VOLUME XLIX NUMBERS 3 AND 4

THE HAWAIIAN PLANTERS' RECORD

Development of 32–8560 cane at the age of four months.
Upper: Planted in May. Lower: Planted in November.
Left: Not fertilized. Right: Fertilized.

THIRD AND FOURTH QUARTERS 1945

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THE HAWAIIAN PLANTERS' RECORD

Vol. XLIX THIRD & FOURTH QUARTERS 1945 Nos. 3 & 4

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association.

A Contrast in Seasonal Effects

The illustration on our cover for this issue shows a contrast in seasonal effects upon the growth of 32–8560 plant cane at Makiki.

These photographs were taken four months after the cane was planted. The upper pictures are of a crop that was planted on May 11, 1942 (this is the crop which furnished the data for the article "The Effect of Nitrogen Fertilization Upon the Yield and Composition of Sugar Cane" which follows). The lower pictures are of a comparable crop that was planted on November 8, 1944, in the same field and within less than 100 feet of the spots where the upper ones were taken.

Both pictures at the left show cane which had not received any fertilizer, whereas both pictures at the right are of cane which had received a nitrogen application of 40 pounds per acre when it was six weeks old.

During its four-month-growth period, the crop planted in May received a total of 1163 hours of sunshine and 1944 day-degrees of temperature; average minimum and maximum temperatures were 71.3 and 85.7 respectively. For the initial four-month-growth period of the crop planted in November, there were 967 hours of sunshine, 1232 day-degrees, and average minimum and maximum temperatures of 64.8 and 80.2 respectively. These seasonal differences, which show approximately 17 per cent less hours of sunshine, 37 per cent fewer day-degrees, and minimum and maximum temperatures of 6.5 and 5.5 degrees less for the crop planted in November, are the only major points of difference between the two crops; their effects are quite distinct in the photographs.

The response to the difference in nitrogen fertilization was very definite on the crop started in May, whereas there was only a very slight response on the November-planted cane at 2½ months after the nitrogen fertilizer was applied.

Two months after these photographs were taken, *i.e.*, when these crops were six months old, the average yields of total green weight harvested from the November-planted crop were still about 50 per cent less.

	Tons green weight per acre	
Planted	Without N	With 40 lbs. N
May 1942	38.1	48.8
November 1944	18.9	24.7

R. J. B.

A Blueprint Sunshine Recorder for Hawaii's Plantations

By R. J. Borden, L. R. Smith, and S. Kobori

The dominant influence of weather upon the growth and composition of sugar cane is quite obvious to those who have worked with this crop, but the relative importance of the individual factors which collectively make up weather has not been clearly defined. Studies of this phase of sugar cane research are handicapped by an inadequate number of instruments with which to measure the various weather factors.

In general the plantation's weather instruments, such as they are, are located at a point chosen for convenience rather than representativeness of the cultivated area for which its measurements are desired; and with the exception of rain gauges, this location is usually a single one at the plantation headquarters. One who knows of the wide variations that exist, especially in rainfall, sunshine, and wind, among the different sections of our large plantation areas will understand that correlations between the weather measurements secured at this single station and the yields of sugar from distant fields are not apt to be reliably established. Apparently, then, we need more instruments so that they can be more widely distributed to cover these major variations of weather within the plantation field boundaries. The best chance we have of getting more installations of such instruments will come if they can be provided at a low initial and subsequent maintenance cost.

With this thought in mind, a blueprint sunshine recorder has been designed and constructed, and after four years' trial at our Makiki station and three years at Manoa and Waipio, we are convinced that it has certain advantages over the instrument now used at many of the plantation weather stations for measuring the duration of sunshine. This new recorder cannot take the place of an expensive pyrheliometer which transforms sunshine into measurable units (grams calories) of sunlight energy, but it is quite positive in its ability to record the duration of sunshine in terms of hours and fractions of hours. It has an initially low cost, is quite foolproof because of its minimum of movable parts, and requires only a very small amount of attention. Hence it provides us with a very simple device to measure one phase of sunlight, *i.e.*, duration of sunshine which undoubtedly has an important effect on sugar yields.

The instrument (see Fig. 1) consists of two half-cylinder and duplicate receptacles, firmly joined together as a single unit, mounted under cover and in such a way that the whole unit can be moved along two small parallel rods. A small sheet of ordinary blueprint paper (sensitive side up) is laid flat along the concave surface in each receptacle to receive the sun's rays through a pinhole in the cover. As the sun moves through the sky its light ray enters this small hole and causes a photographic exposure in the form of a visible line when the blueprint paper is developed (see Fig. 2). When such a ray is obstructed by a cloud, this line is immediately broken and its path is not renewed until the sun shines through again. The result

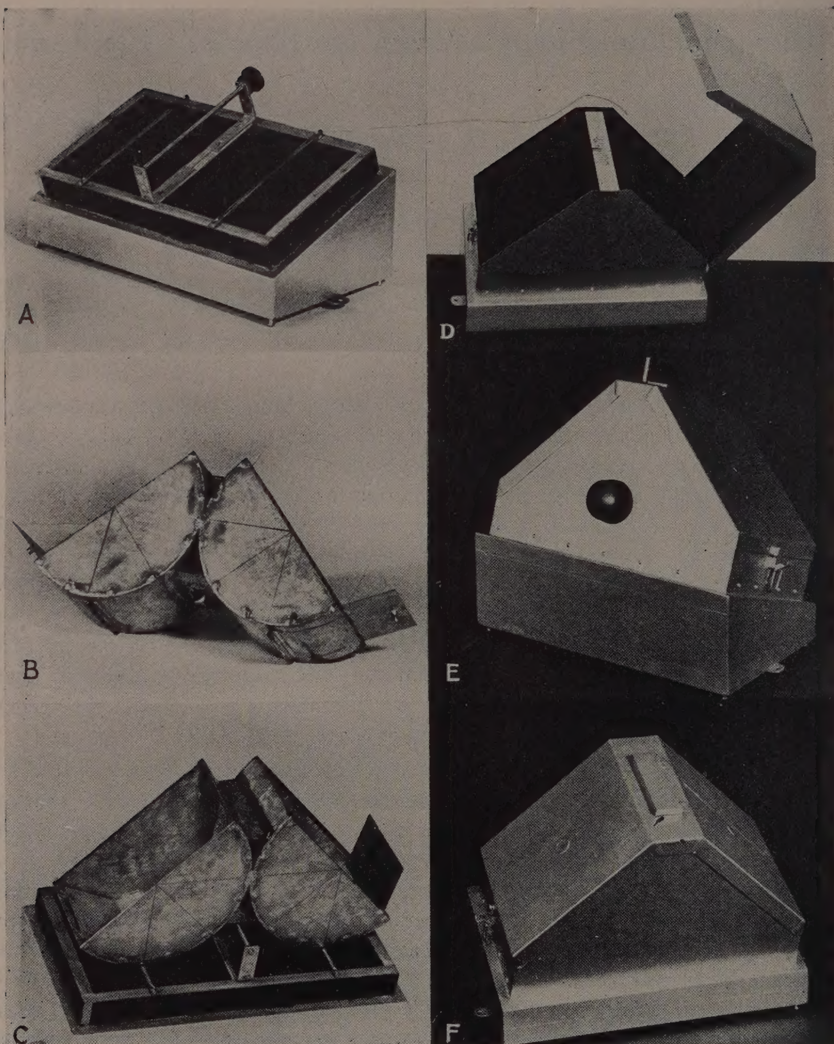

Fig. 1. The blueprint sunshine recorder. *A*—The base; *B*—the twin receptacles; *C*—receptacles mounted on base. *D, E, F*—The completed unit. *D*—Open to show indicator scale above receptacles; *E*—closed, rear view, showing regulator knob and opened window to indicator; *F*—closed, front view, ready to function.

is an unbroken line during a period of continuous sunshine, with intermittent breaks in this line from periods of non-sunshine.

To get the instrument to record a straight line, it has been made (for use in Hawaii) on a base which has been tilted on its front edge and fixed at an angle of 21° 18″ from the horizontal. This angle corresponds to the latitude at Honolulu, but it will be found quite satisfactory for other latitudes within the Territory, *i.e.*, from 22° at Kilauea to 19° at Naalehu.

There are several essential factors governing the installation of the blueprint

recorder that are necessary for its successful operation: (1) It should be located at a spot where the greatest expanse of east and west horizons can be obtained, and away from trees and objects that will come between the instrument and the horizons. (2) It should be mounted on a perfectly level platform atop a sturdy support. (3) It should be set up with its long axis at right angles to a *true north* line; for the Territory this true north will be 10° west or to the left of the magnetic north line which is found with a compass or a surveyor's transit. When correctly set up the instrument is centered on its polar axis and in such a position will record the path of the sun as a straight line.

The instrument is made with a capacity to register one week's record of sunshine on two separate sheets of blueprint paper, one in the right-hand receptacle for sunshine received from sunrise to high noon, and one in the left-hand side for sunshine from noon to sunset. It is necessary to insert fresh sheets of paper only once a week.

Because there is a seasonal shift in the position of the sun from north to south, provision has been made to keep the summer and winter records of the sun's rays within the limits of the narrow strip of paper upon which the record is obtained. Furthermore, to avoid overlapping of consecutive daily records, a slight adjustment of the position of the receptacles is necessary each 24 hours between sunset and sunrise. This adjustment is easily and quickly made without opening the instrument, by means of a thumb screw which moves the receptacles and simultaneously operates a pointer above an indicator scale on its top. This is the only daily attention that the instrument requires.

The blueprint paper upon which the record is to be obtained should be cut to a size of 3¾ by 10½ inches. As in the case with any unexposed blueprint paper it should be protected from bright light, handled carefully (with dry hands) and reasonably quickly. After an exposed sheet has been removed, the top end of a fresh sheet, sensitive side up, is tucked firmly into the groove at the top of the receptacle, carefully smoothed so it will lie flat and firm along the concave surface, and held down at its lower end by the hinged flap. Both receptacles are thus loaded before the cover is closed and the indicator reset for another week's record.

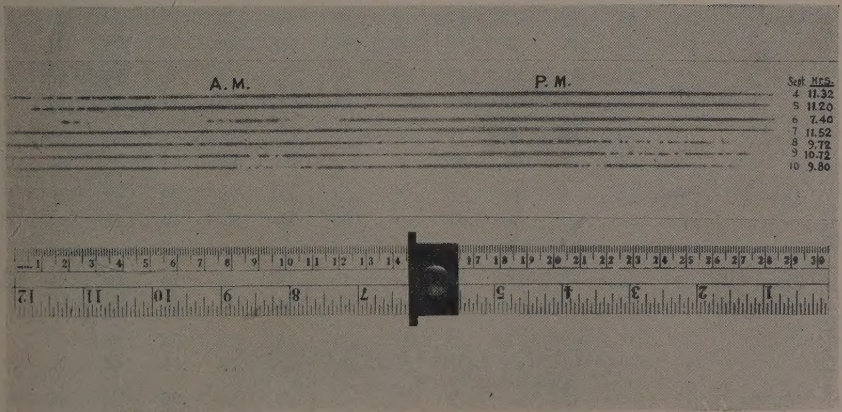

Fig. 2. A week's record of sunshine as recorded on the two strips of blueprint paper which have been joined at their midday points for measuring. Also, rule with slide used to accumulate total length of visible lines for conversion to hours—2.5 cm.=1 hour.

The exposed sheets are removed and placed sensitive side down in a tight box, and kept there until they can be developed. A single point under the hinged flap of the right-hand receptacle will pierce the paper and identify the morning record from that of the afternoon which is similarly pierced but by two sharp points on the underside of its flap. Since the free edge of both flaps marks accurately the position of the sun at noon on both sheets, the sheets when removed and developed may be joined at their mid-day points to get the full day's record. The visible lines which are the sunshine records may then be measured with the proper scale (2.5 cm. equals 1 hour), and the actual hours of sunshine recorded therefrom (Fig. 2).

A 12-month record of comparisons between this blueprint recorder (B) and the sunshine recorder (F) which is generally used at plantation weather stations is given in Table I. It will be noted that in the early morning hours the "B" recorder

TABLE I

A COMPARISON OF THE AVERAGE HOURLY AND DAILY DURATION OF SUNSHINE AT MAKIKI AS OBTAINED WITH THE BLUEPRINT RECORDER (B) AND WITH AN ACCEPTED WEATHER BUREAU RECORDER (F) OF SUNSHINE HOURS

Instru-ment	Month	6–7	7–8	8–9	9–10	10–11	11–12	12–1	1–2	2–3	3–4	4–5	5–6	True daily avg. hours
	1941													
B	April	.28	.69	.72	.77	.67	.73	.69	.69	.66	.61	.54	.21	7.26
F		.06	.53	.73	.79	.79	.90	.90	.84	.81	.65	.53	.09	7.63
B	May	.24	.54	.69	.73	.77	.79	.83	.85	.85	.73	.68	.46	8.16
F		.07	.43	.66	.77	.82	.87	.85	.87	.83	.74	.59	.13	7.65
B	June	.22	.52	.60	.65	.66	.67	.67	.66	.63	.60	.50	.30	6.69
F		.08	.42	.63	.75	.84	.87	.85	.80	.75	.71	.56	.22	7.47
B	July	.11	.46	.68	.78	.85	.90	.89	.90	.83	.83	.77	.56	8.55
F		.03	.36	.70	.90	.97	.99	.97	.98	.92	.86	.74	.32	8.74
B	Aug.	.19	.59	.65	.68	.73	.74	.77	.75	.75	.68	.57	.31	7.41
F		.05	.51	.68	.78	.91	.89	.94	.95	.89	.76	.57	.18	8.12
B	Sept.	.14	.53	.66	.78	.77	.82	.81	.79	.78	.73	.63	.19	7.64
F		.05	.46	.66	.89	.89	.93	.96	.95	.86	.78	.55	.04	8.02
B	Oct.	.02	.37	.57	.63	.65	.59	.54	.53	.57	.48	.34	.07	5.36
F		.01	.25	.55	.75	.81	.79	.74	.70	.65	.49	.17	.00	5.91
B	Nov.	.01	.49	.71	.74	.77	.72	.74	.78	.68	.65	.49	.00	6.79
F		.00	.37	.69	.78	.83	.84	.88	.88	.79	.64	.20	.00	6.91
B	Dec.	.00	.24	.60	.68	.73	.73	.71	.76	.72	.56	.35	.00	6.09
F		.00	.03	.47	.68	.83	.88	.88	.88	.83	.60	.19	.00	6.25
	1942													
B	Jan.	.00	.54	.70	.76	.80	.80	.83	.78	.79	.70	.39	.00	7.09
F		.00	.07	.63	.76	.85	.93	.97	.95	.95	.78	.44	.00	7.33
B	Feb.	.01	.41	.60	.73	.70	.67	.68	.74	.63	.58	.46	.02	6.22
F		.00	.07	.51	.69	.79	.82	.84	.88	.79	.64	.46	.01	6.48
B	March	.12	.40	.62	.76	.79	.72	.72	.70	.71	.68	.58	.16	6.97
F		.00	.12	.44	.71	.84	.89	.90	.79	.78	.66	.52	.02	6.64
Avg. diff. (12 mos.) B over F (hrs.)		+.08	+.18	+.04	—.05	—.11	—.14	—.15	—.13	—.10	—.04	+.06	+.11	—.24

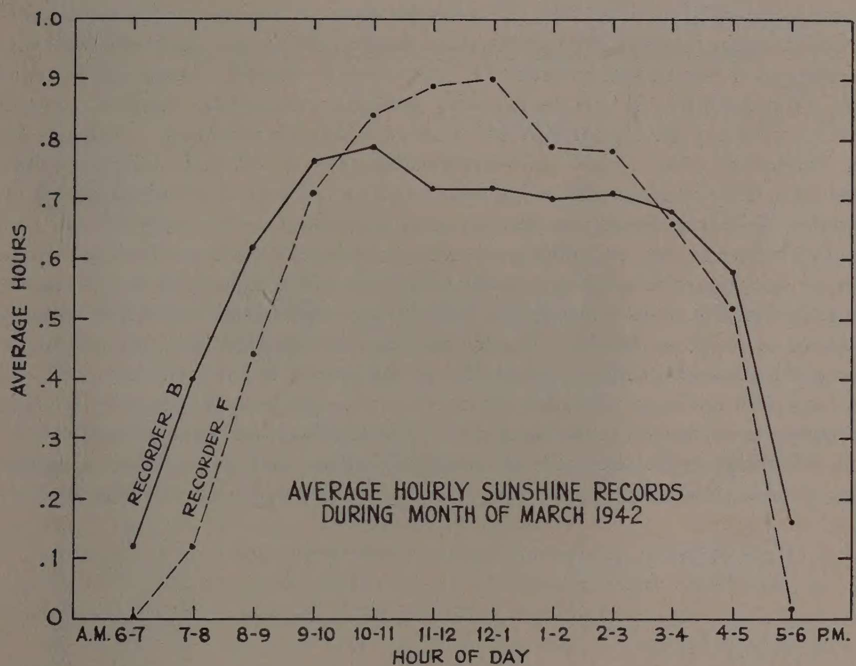
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
AVERAGE HOURS
RECORDER B
RECORDER F
AVERAGE HOURLY SUNSHINE RECORDS
DURING MONTH OF MARCH 1942
A.M. 6-7
7-8
8-9
9-10
10-11
11-12
12-1
1-2
2-3
3-4
4-5
5-6 P.M.
HOUR OF DAY

Fig. 3.

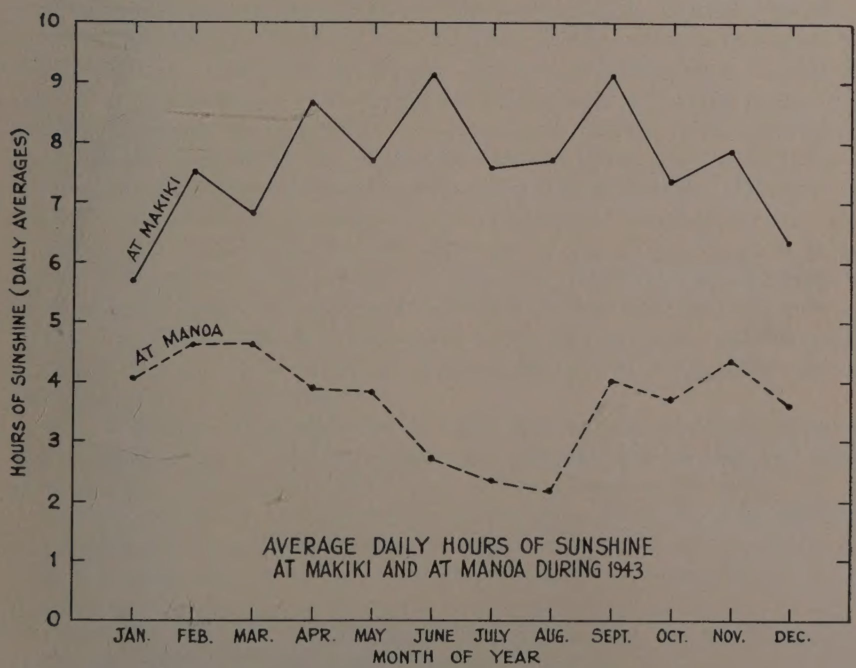
10
9
8
7
6
5
4
3
2
1
0
HOURS OF SUNSHINE (DAILY AVERAGES)
AT MAKIKI
AT MANOA
AVERAGE DAILY HOURS OF SUNSHINE
AT MAKIKI AND AT MANOA DURING 1943
JAN.
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
MONTH OF YEAR

Fig. 4.

shows actual sunshine which the "F" recorder does not register, and a similar difference is again found in the late afternoon hours. As the day advances these differences are reversed and recorder "F" continues to register "something" as sunlight when recorder "B" shows that less sunshine was actually received. Fig. 3 shows graphically the typical differences between the two recorders. Although the two instruments show a high positive correlation ($r = +.90$) their differences have resulted in daily averages amounting to as much as .78 hour or 47 minutes more on recorder "F" for sunshine that was not actually received.

As a matter of interest, and a good example of the differences to be found in the average daily hours of sunshine between two places which are only three miles apart, the graphs on Fig. 4 show that during 1943 Manoa received only about half as many hours of sunshine as Makiki. Furthermore we find an association of the longer hours of sunshine with the cooler months of the year at Manoa, whereas at Makiki the days with the longer duration of sunshine were generally those which enjoyed the higher temperatures at the same time. Someday we shall want to find out how such differences in the interaction of sunshine duration and temperatures can affect sugar yields. This is one of the chief reasons for our interest in this blueprint sunshine recorder.

Nitrogen Depletion by Soil Organisms

By R. J. Borden

The immediate demand for nitrogen by the soil organisms, whose activity is stimulated when organic matter of a wide carbon-nitrogen ratio is added to a soil, creates a deficiency of available nitrogen which manifests itself in an unsatisfactory growth of the immediate crops which follow. This is due to the fact that the nitrogen which becomes tied up in the microbial protoplasm is unavailable, and according to Allen (1—p. 75), "It is doubtful that this nitrogen ever benefits plant growth since it is usually released so gradually that it is dissipated in a very inefficient manner". Hence, when sugar cane leaves or trash are plowed under, or while the decomposition of such organic material is taking place in a good agricultural soil, there will be a depletion of the available soil nitrogen unless an adequate supply of some form of inorganic nitrogen is concurrently supplied.

In an effort to find out how much inorganic nitrogen is needed to satisfy the demands of the soil organisms while they are decomposing sugar cane leaves, we have completed two skirmish tests which have had this objective.

In the first of these tests (No. 172.2) finely chopped cane leaves in an amount equal to 5 tons dry weight per acre (which is equivalent to about 15 tons green weight) were mixed into pots of Manoa soil on March 21. At the same time all pots were uniformly fertilized with lime, phosphates and potash. Different amounts of nitrogen from ammonium nitrate were added to provide nitrogen equivalent to 0, 25, 50, 100, 150, and 200 pounds per acre. The soils were then wet to field capacity, covered, and set aside in a warm greenhouse for a period of 8 weeks, to allow for a considerable degree of decomposition of the organic material before planting. To insure favorable conditions for microorganic activity during the 8-week fallow period, the soils were turned over and re-irrigated at 2-week intervals. This procedure actually resulted in a very thorough decomposition of the leaves that had been added.

At the conclusion of the 8-week fallow period (on May 17), the soils were planted with panicum grass cuttings. A plant crop was harvested at 2 months and the stubble was immediately ratooned (without additional fertilizer) and grown for another 3 months in order to be reasonably certain that all of the available nitrogen in the soil was used up by the crops. Actually, the growth of this ratoon crop was negligible after the first month.

R.C.M. analyses for available soil nitrogen were made at the beginning and end of the fallow period. Total dry weights and total nitrogen in these dry weights were recorded. These data form the basis for the subsequent discussion.

Table I summarizes the soil nitrogen analyses and shows the gains and losses of available soil nitrogen during the fallow period while the soil organisms were active in their breakdown of the organic matter which had been added.

(1) Allen, O. N., 1938. The effect of microbiological activity upon the carbon-nitrogen ratio in soil. Reports Hawaiian Sugar Technologists, pp. 73–75.

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TABLE I

Nitrogen differences: N added in amm. nitr. Gms./pot	(Lbs./ac.)	Amounts (grams) of available nitrogen in soil — Control — no trash: Before fallow	After fallow	Gain or loss*	With trash added: Before fallow	After fallow	Gain or loss*
0	(0)	.592	.628	+.036	.500	.032	—.468
.09	(25)	.682	.784	+.102	.590	.104	—.486
.18	(50)	.772	.928	+.156	.680	.220	—.460
.36	(100)	.952	1.240	+.288	.860	.572	—.288
.54	(150)	1.132	1.604	+.472	1.040	.936	—.104
.72	(200)	1.312	2.008	+.696	1.220	1.248	+.028

*From soil supply only, *i.e.*, not including the N added in ammonium nitrate.

From the natural supply of humus in this soil during its 8 weeks of active fallow, there was a 6.1 per cent increase (+.036 gm. per pot) in available nitrogen in the soil which received neither cane leaves nor nitrogen, but where the trash had been added without nitrogen, the increased carbon-nitrogen ratio provided the conditions for a loss of the original soil nitrogen amounting to 93.6 per cent (—.468 gm. per pot). These are undoubtedly effects from the soil organisms.

Increasing the amounts of nitrogen fertilizer without trash changed the carbon-nitrogen ratio, and the then relatively low level of carbon allowed an increasingly larger amount of nitrogen to be released from the soil's humus supply. Thus nitrogen applied at an equivalent of 25 pounds per acre increased the initial amount (.592 gm.) of available soil nitrogen over and above the amount applied (.09 gm.) by 17.2 per cent. Similarly, the application of 50 pounds per acre increased the initial amount of nitrogen by 26.4 per cent, and the 100-, 150-, and 200-pound applications were responsible for increases of 48.6, 79.7, and 117.6 per cent respectively.

Where the cane leaves had been mixed into the soil, the addition of inorganic nitrogen fertilizer equivalent to as much as 150 pounds per acre was ineffective in reducing the loss of some of the available nitrogen initially present in the humus; only when as much as 200 pounds per acre were supplied was there any release from the original supply, and this was only an increase of 5.6 per cent—slightly less than was secured without any nitrogen from the soil which received no trash.

The total nitrogen recoveries in the total dry matter grown and harvested are summarized in Table II. When no trash was added, the recoveries were considerably greater than when trash was added before fallow. With trash, the application of as much as 100 pounds of nitrogen per acre (.36 gm. per pot) did not result in the release of as much nitrogen for the two crops as the unfertilized soil without trash released. Increasing the nitrogen applications with trash did result in increasingly higher percentage recoveries of the available nitrogen, but even the highest amount used (*i.e.*, .72 gm. per pot or 200 lbs. per acre) did not give a percentage

TABLE II

NITROGEN RECOVERIES IN TOTAL DRY WEIGHT OF BOTH CROPS

Gms. N added	Control — no trash: Total gms. nitrogen: Available	Recovered	Per cent recovered	With trash added: Total gms. nitrogen: Available	Recovered	Per cent recovered
0	.592	.441	74.5	.500	.043	8.6
.09	.682	.547	80.2	.590	.093	15.8
.18	.772	.625	81.0	.680	.182	26.8
.36	.952	.825	86.6	.860	.367	42.6
.54	1.132	.890	78.6	1.040	.598	57.5
.72	1.312	1.063	81,0	1.220	.791	64.8

(There was no *available* nitrogen remaining in these soils after the second crop was harvested.)

Fig. 1. Upper — Plant Crops; Lower — Ratoon Crops.

Control — without cane trash:

1204—no N.	1216—100 lbs. N/ac.
1208—25 lbs. N/ac.	1220—150 lbs. N/ac.
1212—50 lbs. N/ac.	1224—200 lbs. N/ac.

With cane trash at 5 tons/acre:

1228—no N.	1240 —100 lbs. N/ac.
1232—25 lbs. N/ac.	1244 (45)—150 lbs. N/ac.
1236—50 lbs. N/ac.	1248 —200 lbs. N/ac.

recovery from the available nitrogen supply that was equal to the unfertilized soil without trash; apparently this nitrogen has been dissipated.

As we have seen from Table I, when these soils were planted after their fallow period, there were many different levels in their nitrogen content. These differences have been quite nicely reflected in the total dry weights that were harvested; these are summarized in Table III.

TABLE III

TOTAL YIELDS (GRAMS) OF PANICUM GRASS HARVESTED (See Fig. 1)

Nitrogen added (lbs./acre)	Control — no trash 1st crop	2nd crop	Both crops	With trash added 1st crop	2nd crop	Both crops
0	102.3	8.3	110.6	4.3	2.9	7.2
25	121.0	8.3	129.3	20.4	2.7	23.1
50	140.8	12.1	152.9	41.9	4.1	46.0
100	168.1	13.0	181.1	86.0	9.0	95.0
150	188.3	16.1	204.4	133.5	10.1	143.6
200	209.9	15.8	225.7	164.9	11.4	176.3

An interpolation of the data in Table III indicates that when trash was added at 5 tons per acre, a yield equivalent to that from the control without trash or nitrogen, *i.e.,* 110.6 grams, would have come when approximately 116 pounds of nitrogen per acre were also given. This makes it appear that approximately 23 pounds of nitrogen for each ton of dry cane leaves added to the soil must be supplied in order to offset the losses of soil nitrogen to the soil organisms which are active in the trash decomposition. This amount when added to the nitrogen contained in a ton of dry cane leaves (in this case 0.6 per cent or 12 pounds) gives a total of 35 pounds or 1.75 per cent and brings the actual nitrogen content close to the theoretical amount required for, according to Waksman (1—p. 124), "When the plant residues contain about 1.7% nitrogen, there is just sufficient nitrogen to enable the microorganisms to bring about active decomposition, without any additional nitrogen required from the outside and without any nitrogen being liberated as ammonia, until considerable reduction in bulk of material has taken place. [Thereafter] . . . the nitrogen liberated in the decomposition of the proteins is immediately reassimilated by the organisms attacking the non-nitrogenous substances and is synthesized into microbial cell substance."

In the second test (No. 172.3) to find the amount of inorganic nitrogen fertilizer that will satisfy the needs of soil organisms which are stimulated when cane trash is added to the soil, we followed a procedure similar to that already described but added more differentials in nitrogen applications, and grew only one crop of the indicator plant until it ceased growing and showed extreme nitrogen deficiency symptoms. No ratoon crop was grown.

Cane leaves at the rate of 5 tons per acre were mixed into a fresh supply of Manoa soil on October 16. The same inorganic nutrients were added, the soil wet to field capacity and set aside for 7 weeks of fallow, and was turned over and re-irrigated 3 times before being planted on December 4. The crop was harvested 93

(1) Waksman, Selman A., 1938. Humus. Second Edition. The Williams and Wilkins Co., Baltimore. 526 pages.

days after planting, when it was apparent that all available nitrogen had been used up.

The gains and losses in available nitrogen during the 7 weeks of fallow are shown in Table IV.

TABLE IV

N added in amm. nitr. Gms./pot	N added in amm. nitr. (Lbs./ac.)	Amounts (grams) of available nitrogen in soils — Control — no trash: Before fallow	After fallow	Gain or loss*	With trash added: Before fallow	After fallow	Gain or loss*
0	(0)	.624	.640	+.016	.520	.064	—.456
.09	(25)	.714	1.004	+.290	....	....	....
.18	(50)	.804	1.120	+.316	....	....	....
.36	(100)	.984	1.500	+.516	.880	.588	—.292
.54	(150)	1.164	1.904	+.740	....	....	....
.72	(200)	1.344	2.416	+1.072	1.240	1.320	+.080
.90	(250)	1.524	2.784	+1.260	....	....	....
1.08	(300)	....	....	....	1.600	2.276	+.676
1.26	(350)	....	....	....	1.780	2.356	+.576
1.44	(400)	....	....	....	1.960	2.860	+.900
1.62	(450)	....	....	....	2.140	3.116	+.976
1.80	(500)	....	....	....	2.320	3.412	+1.092

*From soil supply only, *i.e.*, not including the N added in the ammonium nitrate.

During these 7 weeks of fallow this soil without trash or nitrogen fertilizer showed a 2.6 per cent increase in its available nitrogen, but when trash was added without nitrogen fertilizer, there was an 87.7 per cent loss of the original amount of this nutrient, which was the result of the microorganic activity stimulated by the addition of this carbonaceous material.

As we noted in the first test, the increased applications of nitrogen without trash brought about a release of correspondingly increased amounts of available nitrogen from this soil's humus supply. With applications of nitrogen at the rate of only 25 pounds per acre there was an increase of 46.5 per cent over and above the amount applied in the fertilizer. From the 50-pound application this increase was 50.6 per cent, and for each successive 50-pound application, there were increases of 82.7, 118.6, 171.7, and 201.9 per cent over the amount (.624 gm.) originally present in the humus supply of this soil. However, when trash was added we note losses rather than gains in available nitrogen until rather large amounts of nitrogen were also given, and it again appears unlikely that any of the original nitrogen was recovered until somewhere between 100 and 200 pounds of nitrogen from fertilizer were added

TABLE V

NITROGEN RECOVERIES IN TOTAL DRY WEIGHT HARVESTED

Gms. N added	Control — no trash: Total gms. nitrogen Available	Recovered	Per cent recovered	With trash added: Total gms. nitrogen Available	Recovered	Per cent recovered
0	.624	.364	58.3	.520	.050	9.6
.09	.714	.453	63.4	....	....	....
.18	.804	.521	64.8	....	....	....
.36	.984	.695	70.6	.880	.292	33.2
.54	1.164	.849	72.9	....	....	....
.72	1.344	1.053	78.3	1.240	.499	40.2
.90	1.524	1.202	78.9	....	....	....
1.08	....	....	....	1.600	.753	47.1
1.26	....	....	....	1.780	.901	50.6
1.44	....	....	....	1.960	1.157	59.0
1.62	....	....	....	2.140	1.337	62.5
1.80	....	....	....	2.320	1.451	62.5

along with the 5 tons of cane leaves that were turned into this soil.

Nitrogen recovered in the total dry weights from this test is summarized in Table V. Again the recoveries were greater when no trash was added, and in this instance it is quite clear that such recoveries were increased by the additional increments of the inorganic nitrogen fertilizer. When the trash was added, it required a supplementary nitrogen application of nearly 400 pounds per acre (1.44 gms. per pot) to effect a recovery equivalent to that from the unfertilized soil without trash.

The actual yields of dry matter harvested from this test are shown in Table VI. By interpolation, these yields indicate that in order to produce a yield equivalent to that where no trash or nitrogen fertilizer were added, supplementary nitrogen amounting to approximately 136 pounds per acre was required when 5 tons of cane

TABLE VI

YIELDS (GRAMS) OF PANICUM GRASS HARVESTED (See Fig. 2)

Nitrogen added lbs./acre	Control—no trash	With trash added
0	108.6	13.5
25	139.4	....
50	146.3	....
100	183.0	82.2
150	192.9	....
200	235.3	155.0
250	265.4	....
300	....	213.4
350	....	241.0
400	....	259.5
450	....	280.9
500	....	289.1

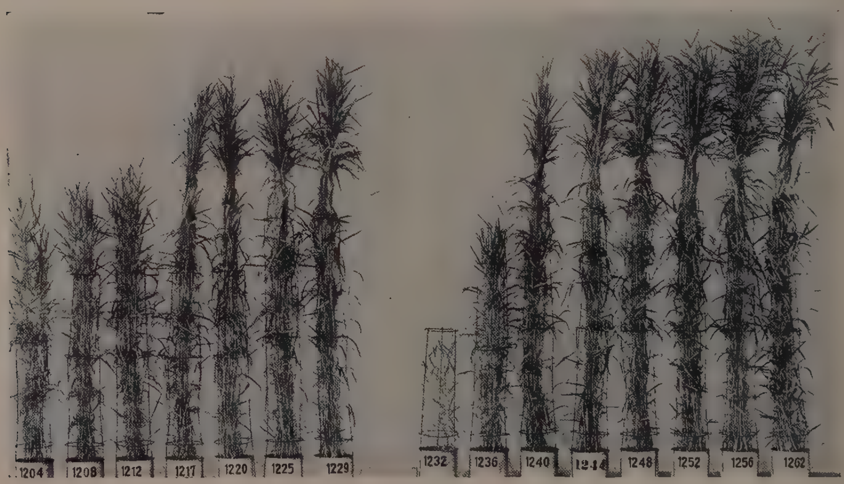

Fig. 2.

Control — without cane trash:
1204—no N.
1208—25 lbs. N/ac.
1212—50 lbs. N/ac.
1217—100 lbs. N/ac.
1220—150 lbs. N/ac.
1225—200 lbs. N/ac.
1229—250 lbs. N/ac.

With trash at 5 tons/acre:
1232—no N.
1236—100 lbs. N/ac.
1240—200 lbs. N/ac.
1244—300 lbs. N/ac.
1248—350 lbs. N/ac.
1252—400 lbs. N/ac.
1256—450 lbs. N/ac.
1262—500 lbs. N/ac.

leaves were mixed into this soil. Hence for each ton of dry cane leaves added, approximately 27 pounds of inorganic nitrogen were needed to offset the nitrogen that was dissipated by the organisms in this soil. This amount together with the 12 pounds contained in the cane leaves makes a total of 39 pounds or 1.8 per cent, which is again very close to the desired theoretical amount for plant residues which will no longer tend to reduce the available nitrogen supply for crops.

Discussion

The cane leaves used in these studies are estimated to have had a carbon content of about 40 per cent, and carried 0.6 per cent nitrogen; this would give them a carbon-nitrogen ratio of about 66 to 1. The greater part of this carbon can be very easily and quickly decomposed by the soil organisms if other conditions are favorable for their activity. Being greatly stimulated by this energy food supply from cane leaves added to the soil, there is an immediate and corresponding demand for nitrogen by these organisms, and they will take it from whatever source is available. This can result in the depletion of the available nitrogen supplies (natural or introduced) to such an extent that the growth of crops will be affected by a nitrogen deficiency. Only by the application of inorganic nitrogen fertilizer can the needs of these organisms be satisfied completely.

From the results secured in these two skirmish tests it appears that approximately 25 pounds of inorganic nitrogen need to be applied along with each ton of dry cane leaves which may be added to the soil of our sugar cane fields. This amount will reduce the C:N ratio created by the added cane leaves to a level which is very close to the theoretical amount (20:1) at which decomposing organic matter no longer has a tendency to tie up soluble nitrogen added to the soil, since, for still further decomposition, sufficient nitrogen will be liberated from the material itself to take care of the needs of the organisms attacking the remainder of the carbohydrate substances.

The Effect of Nitrogen Fertilization Upon the Yield and Composition of Sugar Cane

By R. J. Borden

A continuation of our search for reliable guidance in nitrogen fertilization has added considerably to our knowledge of the effects of nitrogen on the yield and the composition of a sugar cane crop. Although most of the differences which were found are effects from the different amounts of nitrogen applied, there are many interactions between these amounts and their time of application. These in turn are also influenced by the age of the crop when harvested, and it may be that a seasonal effect is also present, although the plan of this study does not allow a separation of the age from the seasonal effects. Furthermore a dominant effect which the nitrogen has had upon the stalk population is brought out, and this effect indicates that many of the differences which were measured were most likely due to differences in the state of maturity of the individual stalks which made up the crop at each of the various harvests.

Introduction

Experiments with the sugar cane crop have shown that it is very exacting with respect to its nitrogen fertilization because both its cane yield and its quality are influenced. Problems which arise are the result of a complex which contains many unknown effects that may enter the picture long after the crop is started, and many of the known direct effects of nitrogen are in turn influenced by these unknowns. The time at which nitrogen fertilizer is given to forestall a nitrogen deficiency is important, especially during the early growth stages, if maximum cane yields are to be secured thereafter. And if the optimum amount of sugar is to be recovered from the cane grown, the time at which a final application is made is also important, in order to avoid an excess of nitrogen which is not completely assimilated before harvest.

There are two main sources of nitrogen for a sugar cane crop—that which comes from the natural soil supply and that supplied by nitrogen fertilizers; two minor sources are that nitrogen which is in the irrigation water, and that brought down in the rainfall. Whatever the source, it is generally conceded that this nitrogen enters the plant by way of the soil. While in the soil, it is known that nitrogen is subject to uptake by the cane itself, by the weeds, and by the many different kinds of soil organisms, and possibly also to removal by leaching. Since the length of this competitive period depends on the rapidity with which the cane crop can take up nitrogen from the fertilizer supplied, any immediate supply of available nitrogen in a soil that is carrying a crop is subject to rather speedy changes. For instance, as the growing cane crop sheds its mature leaves and adds its dead stalks with their individual dead roots, the biological activities which are soon thereafter concerned with the decomposition of these organic materials will play an important part in the effect that is obtained from the total available nitrogen supply; these soil organisms can either

add to or tie up and thus take away some of this natural and applied nitrogen, and the extent of their activity is in turn dependent on so many factors that it is difficult to predict the result for large plantation fields. Moreover, uptake by the crop itself depends on conditions that are optimum for rapid growth; so weather, in all its aspects, exerts an influence on both uptake and assimilation, and we know how difficult it is to predict the elements of weather in Hawaii. All of these factors and undoubtedly many others have their separate and combined influences on the efficiency of applied nitrogen fertilizers and the results we eventually measure therefrom as yields.

The storage of nitrogen in the sugar cane plant is not clearly understood. We do know that the uptake of nitrogen applied can be very rapid, and that a considerable amount of growth follows before deficiency symptoms are thereafter found, but our ability to predict that a specific quantity of nitrogen within the crop at "half-time" will maintain optimum growth without additional nitrogen application during the last half of its growing period has not yet been proved. Moreover the storage of nitrogen is affected by the cane's growth, and if growth-limiting factors other than nitrogen are operative, the nitrogen will be stored in the crop in larger amounts and its subsequent usage when the limiting factors are corrected may be too late for economic results, *i.e.*, it could result in increased cane without increased sugar unless the time to harvest is correspondingly extended to allow the complete assimilation of the stored nitrogen supply.

Since nitrogen fertilization is one of the major problems and an item of considerable expense to the sugar planter, investigations that deal with attempts to understand its effects are especially important. We are devoting much attention to such studies today and have already reported much information from our Waipio Experiment 108 ATN.* The present discussion will deal with our first study from Makiki Experiment 20 ATN, similar in many respects but more extensive in some than the Waipio experiment. Our investigations have again included a study of the influence of nitrogen fertilizer on the yield and composition of cane crops harvested at periodic intervals during their development at Makiki. Especial attention has been given to the identification of specific indices which would show the need for additional nitrogen fertilizer, and at the same time indicate probable levels in some part of the cane plant that are indicative of a sufficient nitrogen supply to grow the crop to the desired age at harvest.

The Plan

An area in Makiki Field 6–7 was used for this study. The soil, a reddish-brown loam, is well drained and has a naturally high supply of available phosphate and potash so that neither of these plant foods needs to be supplied in the fertilizer for sugar cane crops. After a thorough preparation, the area was divided into 50 plots with rows 25 feet long spaced 5 feet apart. Provision was made for 10 nitrogen-

*Borden, R. J., 1942. A search for guidance in the nitrogen fertilization of the sugar cane crop. Part I—The plant crop. The Hawaiian Planters' Record, 46: 191–238.

————, 1944. A search for guidance in the nitrogen fertilization of the sugar cane crop. Part II—The first ratoon crop. The Hawaiian Planters' Record, 48: 271–302.

fertilizer differentials, grouped in each of 5 blocks (Fig. 1). A 3 by 3 factorial plan with its three "amounts" of nitrogen and three "times" of application made up

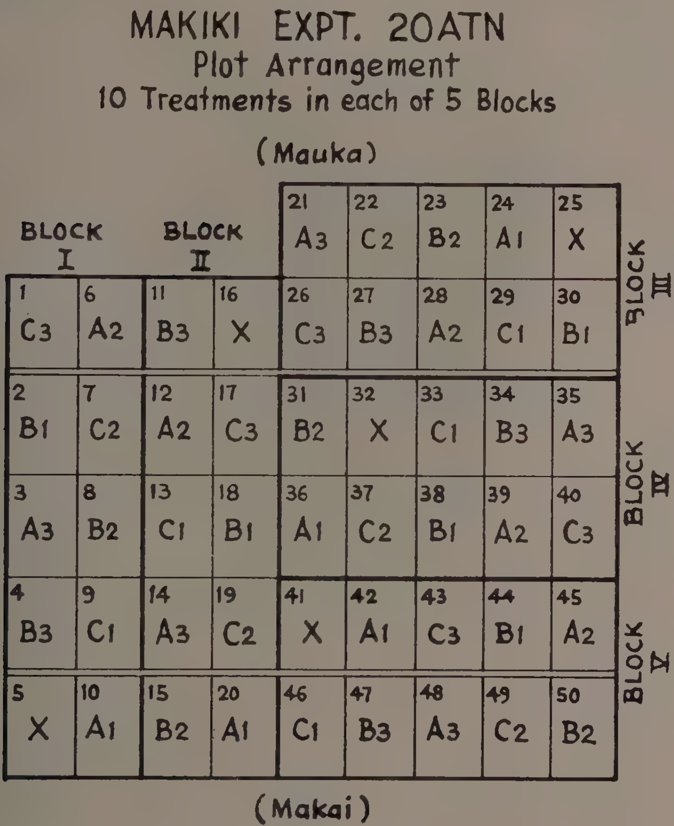

Fig. 1.

nine of the treatments and one "no N" or control plot completed each block. The fertilizer plan was as follows:

PLAN OF FERTILIZATION
(Pounds per Acre)

Treatment identity	No. of plots	At 6 wks. 6/22/42 Lbs. N	At 4 mos. 9/11 Lbs. N	At 6 mos. 11/13 Lbs. N	At 11 mos. 4/11/43 Lbs. N	Totals N	P_2O_5	K_2O
A1	5	40	60	0	0	100	0	0
B1	5	40	120	0	0	160	0	0
C1	5	40	180	0	0	220	0	0
A2	5	40	0	60	0	100	0	0
B2	5	40	60	60	0	160	0	0
C2	5	40	120	60	0	220	0	0
A3	5	40	0	0	60	100	0	0
B3	5	40	60	0	60	160	0	0
C3	5	40	60	60	60	220	0	0
X	5	0	0	0	0	0	0	0

The experimental area was planted with seed of 32–8560 cane on May 11, 1942. Irrigation followed immediately and the resultant germination was excellent. A very small amount of replanting was done on June 2 to insure a completely uniform stand in all rows.

To insure adequate irrigation, rounds during the first six months were made at weekly intervals since the lateral movement of water in this area was somewhat unsatisfactory and its downward penetration was quite rapid. From November 1942 to September 1943 irrigation intervals were of 250 day-degrees, and although no actual wilting or moisture-deficiency signs were ever observed in the leaves, there was an absence of visible succulence in the tops during the second July-August period which some of us interpreted as being due to an inadequate supply of soil moisture; hence the irrigation intervals were reduced to 200 day-degrees and maintained thereat until the final harvest at 27 months. Actually the crop harvested at 15 months had received 35 rounds of irrigation and that at 27 months a total of 53 rounds, in addition to rainfall.

Harvests were made at three-month intervals throughout the crop with extra harvests at 10 and at 11 months. Each harvest required a period of five days and on each day one complete block of 10 treatments was handled. At each harvest, a "sugar-index" sample consisting of the green tops above the attachment of the sixth leaf was taken from five normal first-season stalks within a 10-foot section of cane row in each plot. Thereafter *all* cane growing within this 10-foot section was cut out. All of this material provided the crop samples from which the stalk census was made, the yields obtained, and the composition of many sub-parts determined from laboratory analyses.

On the basis of the stalk census, two similar cane bundles were made up. After total green weights were secured, the stalks in one of these bundles were topped at their growing points, and their millable cane weighed, crushed in the Cuban A mill at Waipio, and the Brix, pol, and total nitrogen in the crusher juices obtained. The duplicate bundle, in which the stalks were not topped however, was further subsampled to provide the desired samples for laboratory analyses. These included the percentages of moisture, sucrose, reducing sugars, total sugars, and total nitrogen from the samples of total green weight. From the "sugar-index" samples the following analyses were obtained: (*a*) per cent moisture and total sugars in the sheaths of the third to sixth leaves, (*b*) per cent moisture and total nitrogen in the blades of these same four leaves, (*c*) per cent total nitrogen in leaf punches from these same leaf blades, and (*d*) per cent sucrose, reducing sugars, total sugars, and amino nitrogen in the elongating cane section.

Statistical Measurements

All measurements and analyses have been examined and studied by an "analysis of variance." This has enabled us to identify and remove a large part of the positional effect from the total error, and also to combine the data for a study of both of the main effects and their interactions. The residual errors are, however, still

quite large (see Table I for coefficients of variation) and indicate the wide varia-

TABLE I

COEFFICIENTS OF VARIATION

Measurements	Harvest number, month, and age (months)										
	1 Aug. 3	2 Nov. 6	3 Feb. 9	4 Mar. 10	5 Apr. 11	6 May 12	7 Aug. 15	8 Nov. 18	9 Feb. 21	10 May 24	11 Aug. 27
In tons per acre:											
For total green weight....	18.8	10.9	9.1	10.6	11.0	10.0	12.4	13.4	13.6	15.6	17.9
For total dry weight......	16.5	11.5	11.7	13.7	11.8	9.3	13.0	9.0	13.1	15.4	20.3
For total red. sugars	26.7	14.8	23.3	23.4	25.0	17.9	19.3	21.3	19.4	25.8	22.0
For total sucrose	20.6	21.3	13.8	14.6	12.7	10.9	14.1	13.8	13.5	16.2	22.3
For total sugars	21.8	17.7	12.2	13.4	12.4	10.6	13.7	13.5	13.4	16.2	21.7
For total mill. cane.......	...	11.9	8.5	10.5	10.2	10.3	12.3	13.0	13.9	15.6	19.0
For total comm. sugar....	...	45.0	15.3	14.2	13.0	11.8	13.7	13.4	14.3	14.6	23.8
In pounds per acre:											
For N in total crop.......	18.4	12.3	14.4	13.4	14.3	14.3	17.0	16.3	14.4	17.0	17.7
In total crop:											
For % tops	...	5.8	8.9	5.9	6.9	7.0	10.0	7.3	9.8	12.4	13.5
For % moisture	1.1	1.2	1.9	1.8	1.5	1.6	1.6	1.6	1.0	1.2	1.8
For % red. sugars	15.7	11.3	26.4	30.0	26.3	19.0	18.2	21.5	14.5	18.1	23.8
For % sucrose	10.5	14.6	5.7	3.8	3.9	4.4	5.5	3.7	2.9	2.7	3.8
For % total sugars.......	9.9	11.6	4.7	3.6	3.8	4.2	5.0	3.2	2.9	2.6	3.3
For % N	6.1	6.7	14.3	12.8	10.6	12.5	11.2	9.5	8.2	7.6	12.0
In leaves only:											
% N in leaf punches	2.2	3.1	4.3	3.6	4.7	5.8	5.9	6.1	4.1	5.4	7.7
% N in entire blades.....	3.9	4.0	7.0	7.7	6.2	6.6	6.4	7.2	6.8	6.0	10.3
% moisture in blades.....	1.2	1.7	1.5	1.7	2.7	1.8	2.6	1.5	2.4	2.2	2.7
% moisture in sheaths....	1.0	1.0	1.4	1.5	1.8	1.6	1.8	1.4	1.5	1.7	1.9
% total sugars in sheaths.	8.6	5.4	8.2	10.2	9.1	12.0	9.9	9.6	12.8	10.2	14.0
Elongating cane:											
% sucrose	51.7	42.9	21.7	17.3	19.5	29.3	27.4	27.9	31.0	21.1	20.7
% red. sugars	18.3	18.5	17.6	33.9	16.3	15.4	13.7	15.8	16.1	20.0	21.4
% total sugars	15.2	11.8	12.0	13.8	10.7	12.2	10.1	12.7	20.0	14.9	15.3
% amino N	23.7	21.0	13.9	19.0	9.9	15.2	11.1	11.0	19.3	13.3	23.6
Crusher juice:											
% N	...	19.0	35.3	23.8	18.2	26.3	21.4	22.2	12.5	20.0	16.7
Cane quality:											
Yield % cane	...	38.0	13.1	6.7	5.7	6.0	6.5	4.4	4.5	4.0	7.8

tion we always find when using short row samples of field-grown cane with their relatively small numbers of individual stalks. Thus many of the differences we have

recorded are statistically not significant (see Table II for indication of significant effects from amounts [A], time [T] or their interaction [X]), and unless we can

TABLE II

SIGNIFICANT EFFECTS OF TREATMENTS

A=Amounts T=Time of application X=Interaction

Measurements	Harvest number, month, and age (months) 1 Aug. 3	2 Nov. 6	3 Feb. 9	4 Mar. 10	5 Apr. 11	6 May 12	7 Aug. 15	8 Nov. 18	9 Feb. 21	10 May 24	11 Aug. 27
Tons per acre:											
Total green weight	**A**	**A**	**A X**	**A**	**A X**	**A T**	**A** X	**A X**	**A** X	**A**	**A**
Total dry weight	**A**	**A**	**A** T X	**A**	**A** X	**A T**	**A** X	**A** T **X**	**A** T **X**	**A**	**A**
Total red. sugars	**A**	**A**	**A**	**A**	**A**	**A T**	**A T**	**A**	**A** X	**A**	A
Total sucrose	ns	**A**	**A T**	**A**	**A X**	**A T**	**A** X	**A X**	**A** T **X**	**A**	**A**
Total sugars	A	**A**	**A T** X	**A**	**A X**	**A T**	**A** X	**A X**	**A** T **X**	**A**	**A**
Total mill. cane	..	**A**	**A** T **X**	**A**	**A X**	**A T**	**A X**	**A X**	**A** X	**A**	**A**
Total com. sugar	..	**A**	**A T**	**A**	**A** X	**A T**	**A X**	**A X**	**A X**	**A** X	**A**
Lbs. N in crop..............	**A**	**A**	**A**	**A** T	**A X**	**A**	**A**	**A X**	**A** T **X**	**A**	**A**
Total crop:											
% tops	..	**A**	A	**A** T **X**	**A** T **X**	**A** T	**T X**	**A X**	ns	ns	**A**
% moisture	**A**	**A**	**A**	**A**	**A**	**A**	**T**	**A**	**A** X	ns	ns
% red. sugars	**A**	**A**	**A**	**A**	**A**	**A**	**T**	A	ns	ns	ns
% sucrose	ns	**A**	**A**	**A**	A	ns	ns	ns	ns	**A**	**A**
% total sugars	ns	**A**	**A**	ns	A	ns	ns	**A**	ns	**A**	**A**
% N	**A**	**A**	**A**	**A**	**A**	**A**	**A T**	**A**	**A X**	**A**	ns
Leaves only:											
% N in leaf punches........	**A**	**A**	**A**	**A**	**A**	**A T**	**A** T	**A**	**A** X	ns	ns
% N in leaf blades	**A**	**A**	**A**	**A**	**A**	**A T**	**A** T	**A**	**A**	ns	ns
% moisture in leaf blades....	**A**	**A**	**A**	**A**	ns	ns	**A**	**A X**	ns	ns	ns
% moisture in leaf sheaths...	**A**	**A**	**A**	**A**	**A**	**A**	**A**	**A**	**X**	ns	ns
% total sugars in leaf sheaths	ns	**A**	X	A	A	**A**	ns	ns	ns	ns	ns
Elongating cane:											
% sucrose	A	ns	ns	T	ns	ns	**A**	ns	ns	ns	ns
% red. sugars	A	ns	ns	**X**	ns	**A T**	**A**	**A**	**A**	ns	ns
% total sugars	**A**	**A**	ns	ns	ns	**T**	ns	ns	ns	ns	ns
% amino N	ns	A	**A** X	**A**	**A**	**A** T	**A** T	**A**	ns	**A**	ns
Crusher juice:											
% N	..	**A**	**A**	**A T**	**A**	**A**	**A** X	**A**	**A**	**A**	**A**
Cane quality:											
Yield % cane	..	**A**	**A**	**A**	**A**	**A**	T	**A** X	X	**X**	ns

Note: Treatment identity in bold-face type indicates high significance; ns=not significant.

rationalize their existence, they can be only tentatively accepted. Fortunately many of the differences can be rationalized as the effects of the treatment applied, although there may be some doubt as to the actual magnitude of the specific effect which is identified.

Observations

At 3 months (*August 10, 1942*): A full stand and a comparable and satisfactory growth appear in all plots; stooling has been excellent. Leaf-color differences between the fertilized and non-fertilized cane are not distinct. The actual number of stalks per foot of row is about 11 in the fertilized plots, but there are fewer stalks in the non-fertilized plots.

At 6 months (*November 9*): The growth has been exceptionally rapid and stalks now have considerable millable cane. Treatment X has now "yellowed-off"

and has many dead shoots. Both Treatments A2 and A3 also show nitrogen deficiency symptoms and many of their small shoots are dead. Treatments B1, C1, and C2 have a very heavy and succulent growth with long joints and a dark-green leaf color.

On November 13 and 14, heavy winds flattened much of the cane in this field and a relationship between heavy early nitrogen fertilization and the extent of the lodging was observed. Thus the cane in all plots which had already received a total of 160 or 220 pounds of nitrogen was badly lodged; that in plots which had received 100 pounds had some badly lodged spots, especially in those plots on the windward edges (Nos. 23, 24, 1, 11, and 40), but there was no lodging in the 10 plots which had received only 40 pounds of N and none in the "no N" plots.

At 9 months (*February 8, 1943*): There is a tremendously heavy tonnage of very succulent cane in the field at this harvest, and non-millable suckers have already made an appearance, more especially in the B and C plots. The leaf color in Treatments B and C is still good but all of the A plots now show N-deficiency symptoms.

At 10 months (*March 8*): Heavy rain (2.2 inches) fell in the 24 hours preceding this harvest. Leaf color is still good in the plots which have been most liberally fertilized (Treatments B and C) and still unsatisfactory in the A and X plots. Suckers now have a few joints of millable cane. The tops appear much reduced in size and the youngest leaves are quite close together in all treatments.

At 11 months (*April 12*): The cane in the X and A3 plots is very yellowish, and that in the other treatments although not actually a yellow-green is not however as dark green as formerly. Also the tops appear quite shortened and the leaves less succulent than in previous harvests.

At 12 months (*May 10*): A total of 1.75 inches of rain fell during the first three days of this 5-day harvest. Some primary stalks which had made millable cane were now found with dead tops, more especially in the C and B treatments which had lodged in November. An abundance of new suckers has appeared, also most prominently in the C and B plots; actually about half of the total stalk population is now made up of suckers which have appeared within the past few months and are developing very rapidly. There are no really dark green leaves at this harvest; the leaf color in Treatment A3 which received nitrogen last month is indistinguishable now from leaves in the other fertilized plots, but the leaves from A3 are considerably narrower.

At 15 months (*August 9*): Suckers with millable cane and large tops are now a definite part of the crop, and fewer non-millable suckers were found. Leaf color is definitely a yellow-green in all treatments and the leaves themselves appear dry, although irrigation does not visibly change this characteristic and they have not shown any actual wilting.

Between 12 and 15 months a series of growth measurements were made from the 5 plots of Treatment C3 which had received 220 pounds of nitrogen. Five primary stalks and five adjacent suckers were marked in each plot. The average growth rate (inches per day) of the 25 primary stalks was slow, but the adjacent suckers were elongating just about twice as fast as the primaries in the same stools:

AVERAGE ELONGATION (Inches per Day)

	June	July	August
Primary stalks	.132	.132	.168
Suckers	.264	.252	.324

At 18 months (November 8): This harvest was characterized by the finding of a large number of dead primary stalks, 15 to 18 feet long. Many of them had died from dead tops which had evidently been smothered out, but many more had dead or dying sections (between butts and tops) which were the result from sour rot entering the "splits" so commonly found in 32–8560 stalks which have developed rapidly. Growth was still slow although irrigation intervals had been decreased to 200 day-degrees in September. The highest yield of millable cane obtained from any individual plot came from No. 26 (Treatment C3) at this 18-month harvest—169 tons per acre.

At 21 months (February 7, 1944): More dead primaries (especially from split stalks) again characterized this harvest, especially from the B and C plots, and there were also a measurable number of dead suckers which had previously formed some millable stalk. Large diameter and heavy millable suckers were now almost as numerous as the sound primaries and the Brix in the dry-leaf portion of some of these suckers was found to be over 20. The primary stalks seemed to have almost stopped growing in all plots regardless of the previous N treatments.

At 24 months (May 8): The dying of the primary stalks has continued and there are now more millable suckers than primaries. Moreover another young crop of suckers has appeared although there are many of these which are dying too, as they appear to be weakened after pushing up through the dense layers of trash (dropped leaves). The leaf blades still feel tough and are especially sharp at the edges, although irrigation has been sufficient to prevent any leaf-curling which precedes wilting.

At 27 months (August 7): Deterioration of the cane has been rapid and the field has had a distinctly sour smell for several months. The crop is now composed largely of the first-season suckers. Dead primaries with 18 to 20 feet of stalk are more numerous than live ones. The loss of cane and sugar has been large.

Soil Nitrogen

Monthly Soil Analyses for Available Nitrogen:

Soil samples were taken each month from the surface foot in the row middles from the five "X" plots which received no nitrogen fertilizer. These were tested by our Mitscherlich test to determine the availability of nitrogen therein. The results shown in Fig. 2 give us an idea of the amount of natural soil nitrogen that was present in this field throughout the cropping period. As previously observed in soils soon after their plowing, the available nitrogen supply increased (from 40 to 80 pounds) until the crop had "covered-in" (September) and cane roots had spread throughout the interlines. Thereafter a sharp decline occurred which incidently coincided with the decreasing temperatures of the winter season. With the advent of warmer weather the available N supply increased to more than 60 pounds, only to decrease again as another fall and winter came along. This seasonal effect on the available N supply continued to repeat itself, but the extent of the increase which followed February 1944 was surprising and totally unexpected. It was most likely that this increased supply of nitrogen (to more than 100 pounds per acre) greatly stimulated the new crop of suckers that were found three months later in all treatments; its occurrence presents just one more complication in our attempts to provide optimum nitrogen fertilization for a crop of sugar cane.

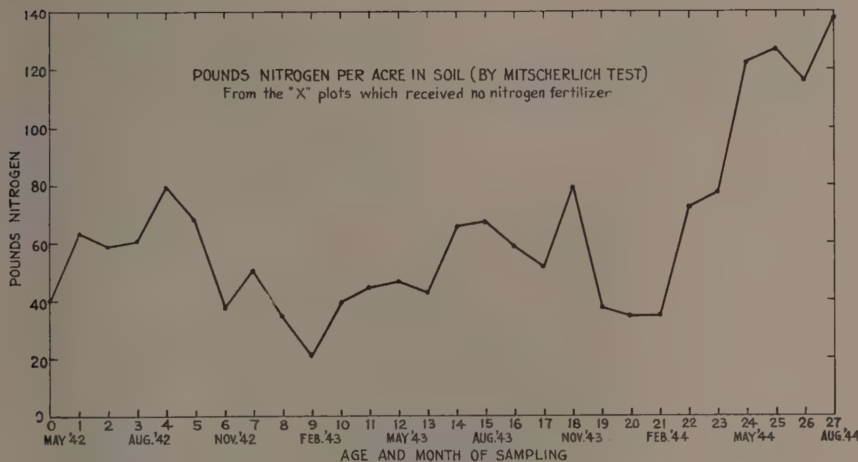

Fig. 2.

Crop Composition

The Stalk Population:

The general character of the stalk population and the influence of the different nitrogen treatments on it can be seen in Fig. 3. A breakdown of the total population at the second year's harvests, showing the relative numbers of live and dead

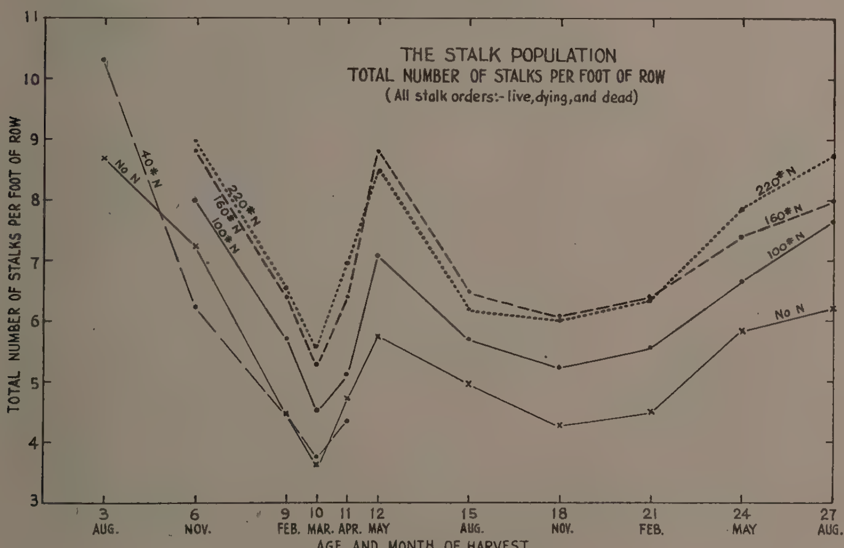

Fig. 3.

primaries and also of millable and non-millable suckers, is illustrated in Fig. 4.

The higher nitrogen applications have produced the greater total numbers of stalks and thus created the more dense stalk populations. However, these higher

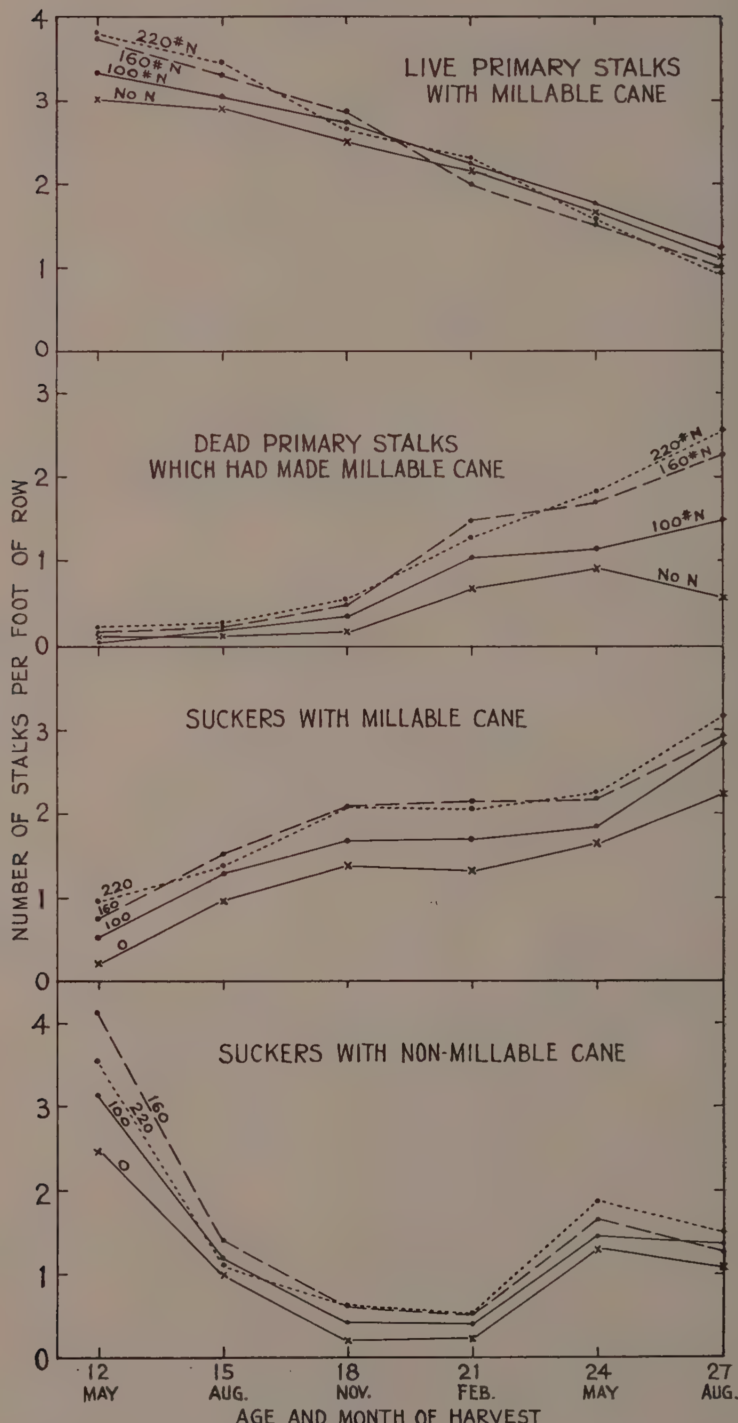
LIVE PRIMARY STALKS
WITH MILLABLE CANE
220#N
160#N
100#N
No N
DEAD PRIMARY STALKS
WHICH HAD MADE MILLABLE CANE
SUCKERS WITH MILLABLE CANE
220
160
100
0
SUCKERS WITH NON-MILLABLE CANE
NUMBER OF STALKS PER FOOT OF ROW
12 MAY
15 AUG.
18 NOV.
21 FEB.
24 MAY
27 AUG.
AGE AND MONTH OF HARVEST

Fig. 4.

applications have been responsible for more dead primary stalks after the first year of growth, and they have likewise stimulated more sucker growth than the lower amounts. Both of these factors, dead primaries and suckers with millable cane, can adversely affect the crop's quality if they are included in the cane that is milled. In these studies the suckers were included but the dead canes were discarded before milling; hence our figures which represent quality (Y%C) are higher than they would be if the dead canes had been included, and the differences that we have identified as treatment effects on Y%C would actually be somewhat greater under the present mechanical harvesting methods that are used on plantations.

In as much as it is recognized that both millable suckers and dead or dying stalks affect cane quality, and since both of these factors are influenced by the nitrogen fertilization, a large part of the well-recognized effect of nitrogen on juice quality is most likely a direct effect of the nitrogen on the stalk population.

The progressive changes in the stalk population are quite definite and similar, regardless of the nitrogen differentials. It is not clear whether these are due to seasonal or to age effects, or to a combination of both. The crop started out with a much larger population than it was able to maintain, and by the time it was covered-in some mortality of the smaller stalks was apparent. For the first 10 months the crop was composed entirely of what we have termed primary stalks, which include all the stalks that had appeared within the first 6 to 8 weeks. Thus those crops which were harvested at 10 to 12 months were made up of stalks which were not greatly different in their ages, and since there were few dead millable stalks and only a few millable suckers at this time, a relatively uniform state of maturity existed. This condition resulted in crops of satisfactory quality and excellent sugar recovery at only 11 or 12 months of age.

The coming of warmer weather after the crop was 10 months old brought more sucker growth, and the total stalk population reached another high point in May, just 12 months after planting. Thereafter there was another decline which continued for another 6 months through November; this was especially prominent in the non-millable sucker groups, although some of these were being added to the millable suckers. Part of this decline was also due to the dying of primary stalks. Thus the stalk population harvested at 15 and 18 months was extremely heterogeneous and its non-uniform state of maturity resulted in crops of poorer quality than had been secured earlier.

There was little change in the character of the sucker growth between November and February (18 to 21 months) but the heaviest mortality of primary stalks occurred during this period. The effect of this mortality on the cane quality in this investigation is not reflected in the Y%C figures as we did not mill any dead stalks. Thus without these dead canes, and with no material change in the numbers of suckers, we have secured a very satisfactory quality at 21 months. (*Note:* It will be recognized that this result would not be obtained from mechanical harvesting which results in many dead stalks being milled along with sound ones.)

An increase in the population was again found after 21 months as the warmer weather came along. This is seen by the large increase at 24 months in May of non-millable suckers which became millable three months later.

Of particular interest is the fact that the nitrogen differentials had relatively little effect on the average numbers (for all treatments) of millable primary stalks

which were found alive and sound after 12 months. Age effects, however, reduced the number of live primaries but at the same time the number of millable suckers was increasing.

Age	Average number of sound canes per foot of row		
	Primaries	Suckers	Total
12 months	3.47	0.62	4.09
15 months	3.19	1.30	4.49
18 months	2.71	1.82	4.53
21 months	2.19	1.83	4.02
24 months	1.65	1.99	3.64
27 months	1.09	2.80	3.89

Per Cent Tops (Table 1 in Appendix):

A study of the averaged data which give the percentages of tops shows that these figures dropped sharply from 36.1 per cent at 6 months to 20.9 per cent at 12 months. During the following 6 months this percentage was further reduced to 12.6 per cent and at 24 months it was down to 10.7 per cent.

An effect of the differences in nitrogen treatments was found in several harvests. At 6 months the nitrogen-fertilized canes had a lower ratio of tops to stalks than the non-fertilized "X" plots, and this was quite generally true in subsequent harvests. At 10 and 11 months those plots which had their total nitrogen application of either 100 or 160 pounds completed at 4 months had a lower per cent tops than those completed at 6 months. At 12 months lower per cent tops were still found in the earlier fertilized canes, and this was true also at 15 months in the case of both the 100 and 160 pounds N totals, and at 18 months for the cane which had received a total of only 100 pounds. After 18 months these influences of nitrogen on the per cent tops were not significant.

These figures for per cent tops have greater value when they are turned into actual amounts (tonnages) per acre, for then we get some idea of the total amount of green cane leaves that are active in photosynthesis at different crop ages, and we can study the effects from the different nitrogen treatments upon this total amount of sugar-making equipment.

AVERAGE TONS PER ACRE OF GREEN TOPS

At 3 mos. in Aug. '42	At 6 mos. in Nov.	At 9 mos. in Feb. '43	At 12 mos. in May	At 15 mos. in Aug.	At 18 mos. in Nov.	At 21 mos. in Feb. '44	At 24 mos. in May	At 27 mos. in Aug.
10.5	21.6	22.6	19.5	16.2	15.7	13.0	11.1	10.4

The maximum amount of green tops and hence of the sugar manufacturing leaf area was found in the crops at 6 and 9 months in November 1942 and February 1943. The corresponding amounts for the same calendar months of the following years when the crop was 18 and 21 months old were considerably smaller, even though favored by slightly higher temperatures and more hours of sunshine in the period when these green leaves were appearing. This suggests the great importance of providing against the possibility of having any limiting growth factors during this early growth stage when the basic green-leaf area for sugar manufacturing by the cane plant is at its optimum.

The effect of nitrogen fertilization upon the amount of green tops is quite sig-

nificant, and both the amount of nitrogen used and its time of application are involved, as the following illustration will show:

YIELDS OF GREEN TOPS AT PROGRESSIVE HARVESTS, FROM DIFFERENT AMOUNTS OF NITROGEN APPLIED BY THE SIXTH MONTH

Pounds N applied	Tons per acre At 6 mos.	At 9 mos.	At 12 mos.	At 15 mos.	At 18 mos.	At 21 mos.	At 24 mos.	At 27 mos.
0	15.9	12.8	13.1	9.8	9.0	7.4	7.1	9.3
100	17.0	20.9	17.4	15.0	13.0	13.5	10.7	12.2
160	22.3	26.6	20.8	16.4	17.0	14.8	10.1	9.9
220	25.0	26.4	23.2	17.4	19.1	14.7	13.2	12.5

YIELDS OF GREEN TOPS AT DIFFERENT AGES AT HARVEST, FROM 220 POUNDS OF NITROGEN APPLIED AT DIFFERENT TIMES

220 lbs. N applied as follows: At 1½ mos.	At 4 mos.	At 6 mos.	At 11 mos.	Tons per acre At 6 mos.	At 9 mos.	At 12 mos.	At 15 mos.	At 18 mos.	At 21 mos.	At 24 mos.	At 27 mos.
40	180	0	0	25.3	26.9	22.5	17.7	15.3	14.4	11.1	12.0
40	120	60	0	25.0	26.4	23.2	17.4	19.1	14.7	13.2	12.5
40	60	60	60	22.3	26.6	20.7	19.5	20.0	16.7	13.5	12.6

The higher amounts of nitrogen have not only produced more green tops but have maintained more tops throughout the second year of growth; this should be a desirable feature especially during the first half of this second year. A similar effect has been obtained when a liberal total amount of nitrogen (220 lbs./ac.) was split and given to the crop in four applications, the last one being given at 11 months in April.

Nitrogen deficiency in the early growth stages has resulted in a smaller amount of green-leaf surface too. Thus, when the initial nitrogen application at 1½ months was only 40 pounds per acre, if a subsequent application of 60 pounds was delayed, the amounts of tops were affected as follows:

Second N application delayed until	Tons of tops harvested At 6 mos.	At 9 mos.	At 12 mos.
4th month	22.3	25.3	18.0
6th month	17.0	20.9	17.4
11th month	17.0	16.9	15.3

But when the total amount applied by the fourth month was as much as 100 pounds per acre, a delay in a subsequent application was not especially detrimental to the amount of tops in the field during the first year's growth, *i.e.*,

Subsequent N applied at	Tons of tops harvested At 6 mos.	At 9 mos.	At 12 mos.
6 months	22.3	26.6	20.8
11 months	22.3	25.3	20.7

Crop Analyses

Per Cent Moisture in Total Green Weight, Leaf Sheaths, and Leaf Blades (Tables 2, 3, and 4 in Appendix):

The general relationship between the moisture percentages in the total green weight, leaf sheaths, and leaf blades is shown in Fig. 5. There are a few differences in the slopes of the lines between successive harvests, but a more detailed study of the complete data shows good correlations to exist between the moisture in these different parts of the crop. Thus the correlation coefficient (r) between the mois-

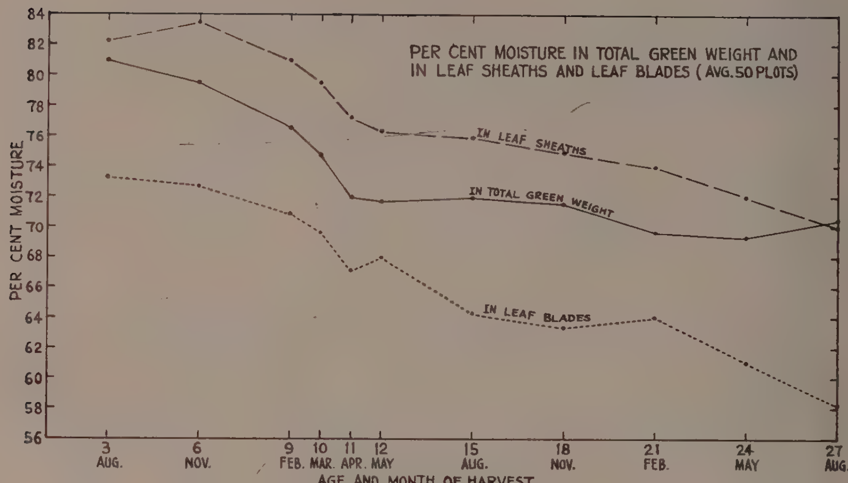

Fig. 5.

ture: (1) of the leaf sheaths and leaf blades is +.96; (2) of the sheaths and total green weight is +.90; and (3) of the blades and total green weight is +.83; so any one of these plant samples should give us a reliable index of the internal moisture condition of the crop. However, since we found a slightly higher amount of variation (Table I) for per cent moisture in the leaf blades than in the leaf sheaths, we would expect that the use of sheath or of total green weight samples would be preferred for moisture determinations.

The effect of nitrogen applications on the per cent moisture was very definite, with increases being secured as each additional increment of nitrogen was supplied (see Fig. 6). The effect, however, is largely one from the total amounts of nitrogen (Fig. 7), with little influence from the time of application, although there are

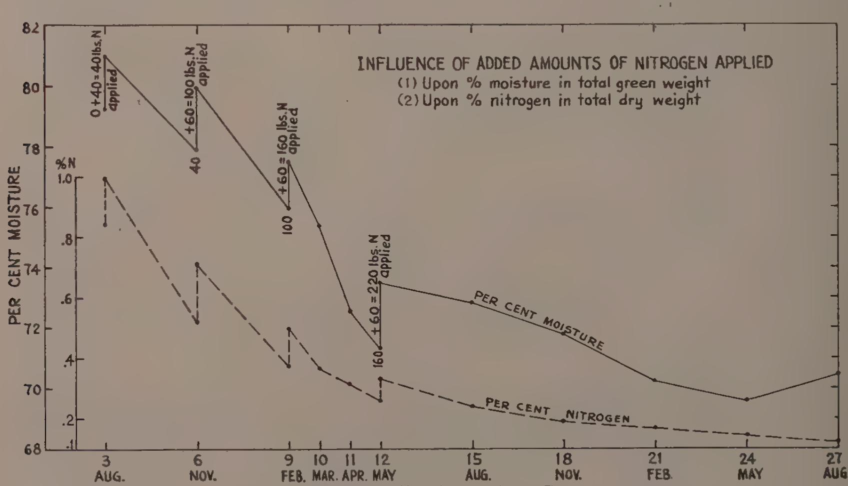

Fig. 6.

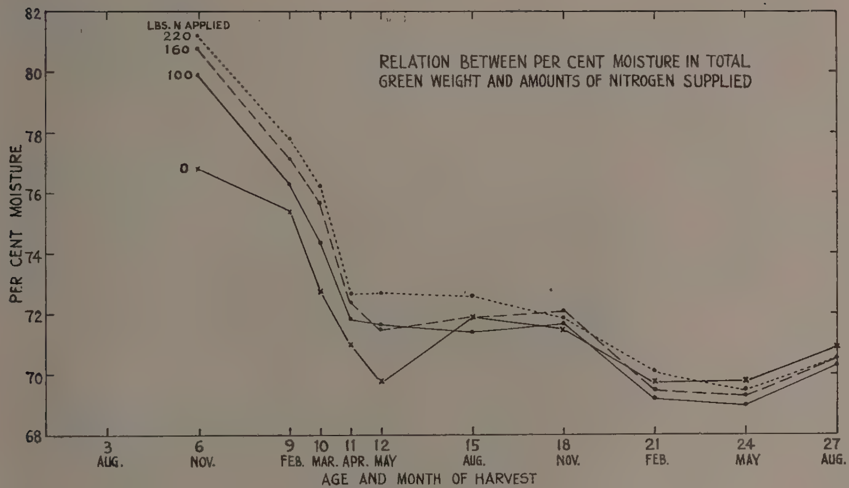

Fig. 7.

a few exceptions; thus: (1) at 15 months there were higher percentages of moisture from a late application of nitrogen made at 11 months than from an earlier application at 4 months, and (2) at 21 months the influence from the amounts was modified by the time of application, *i.e.*, the increases in per cent moisture were found chiefly when plots getting the larger total amounts received a late application at 11 months.

Per Cent Reducing Sugars (*Tables 5 and 6 in Appendix*):

Fig. 8 shows that the average percentage of reducing sugars in the total dry weight reached a point under 2 per cent as early as 12 months and remained low

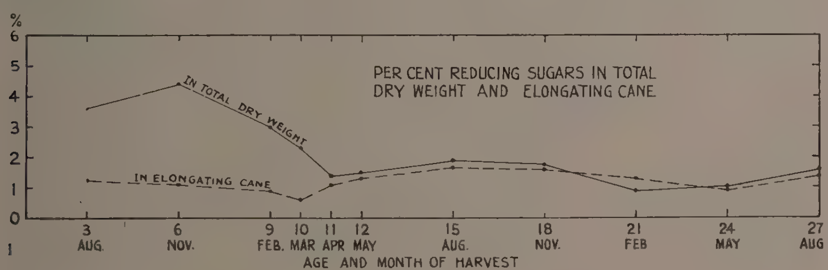

Fig. 8.

thereafter, showing only a slight rise as the second-year suckers began to exert an influence on the crop's stalk population.

The general effect of nitrogen was to increase the concentration of the reducing sugars. Such an increase was rather consistently obtained in the total dry weight from cane which had received the larger nitrogen applications; and to a lesser extent, it was also reflected in the analysis of the elongating cane (the most actively growing plant tissue in that part of the stalk above the attachment of the sixth green leaf and including the growing point).

At both the first and second harvests, the percentage of reducing sugars was higher in the crop which had been given 40 pounds of N than in the controls which had received no nitrogen, but after 6 months the difference had disappeared.

At 6 months higher concentrations were found in the dry weights of the cane that had received more than 100 pounds of nitrogen.

At 10 months, the reducing sugar analyses of the elongating cane showed an interaction between the amounts of nitrogen and the time of application, and a similar trend though not significant was found in the total dry weight analyses. Thus the percentage of reducing sugar was higher from the 6th-month application than from the 4th-month application which brought the total amount in both cases to 220 pounds, whereas with lesser totals, this effect of time was not significant.

At 12 months the differences between the 160 and 100 pounds treatments were too small to be significant, but there was still a higher percentage in the cane that had received 220 pounds. Moreover a similar trend was again found at 15 months, although in this latter case an influence of the time of application again showed higher concentrations of reducing sugars from the later applications at 11 months than when the same total amounts were given earlier.

At 18 months the differences were quite small and at later harvests these effects from the different nitrogen treatments on the per cent reducing sugars were not again identified, except in the elongating cane at 21 months.

Per Cent Sucrose (Tables 7 and 8 in Appendix):

The changes in the percentage of sucrose that came with the increased age of the crop is shown in Fig. 9. The greatest increase occurred between 6 and 11

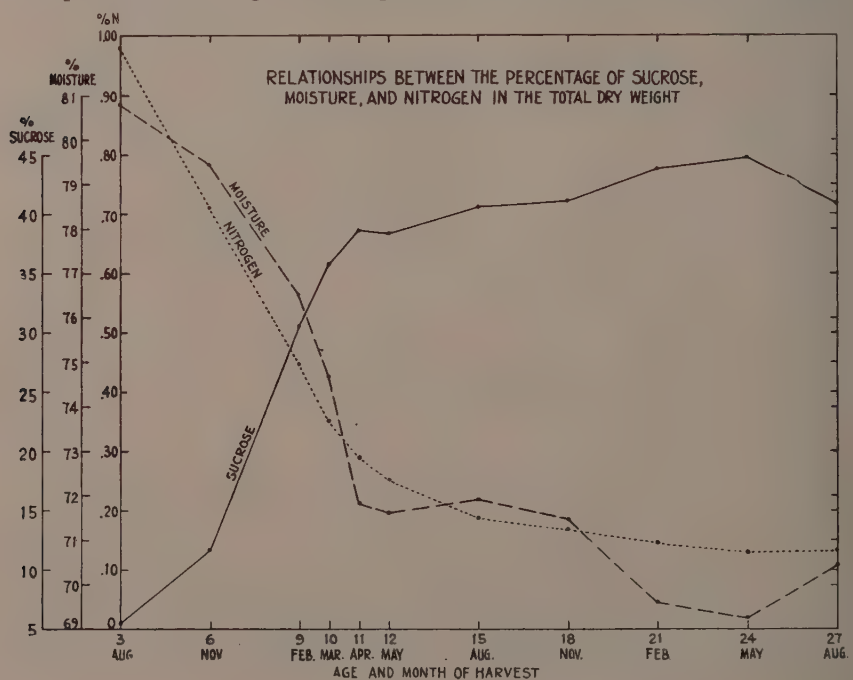

Fig. 9.

months, and most likely is the result of the primary growth reaching its optimum maturity. After 12 months the rate of increase in per cent sucrose was slower but quite uniform until the crop was 24 months old; thereafter there was a sharp drop as the deterioration of the crop became more acute.

In Fig. 9 we show also the inverse relationship between the percentage of sucrose and the percentages of moisture and nitrogen in the total crop samples.

An influence of the different amounts of nitrogen upon the concentration of sucrose in the total dry weight was found to be significant at several of the harvests. A similar effect was suggested but was not always as clearly identified from the per cent sucrose of the elongating cane. Thus at 6 months we found the highest per cent sucrose (14.6) in the cane which had then received only 40 pounds of nitrogen. That cane which had been given either 100 or 160 pounds of N had lower concentrations (11.7 and 11.1) than the 40 pounds treatment, and from 220 pounds of N a still lower amount (9.2 per cent) was found.

At 9 months, the per cent sucrose was still highest in the cane from the lowest nitrogen treatments and now there was no difference between the 160- and 220-pound treatments, both of which, however, had lower concentrations than the cane which had been given only 100 pounds. At 10 months lower concentrations were still the effect from each increase in nitrogen applied, although the differences were now getting smaller, and at 11 months the 100-, the 160-, and the 220-pound treatments had produced cane which did not show the treatment effects on this constituent, all having in the neighborhood of 38½ per cent sucrose.

Differences in per cent sucrose at 12 and at 15 months were still not identified as treatment effects from the total dry weight samples, but in the elongating cane at 15 months, there is confirmation of the fact that each added increment of nitrogen was still producing cane with a lower concentration of sucrose. After 15 months the treatment effects on sucrose concentration had practically disappeared, except that the no-N fertilized cane was consistently poorer than that which did get nitrogen fertilizer.

Per Cent Total Sugars (Tables 9, 10, and 11 in Appendix):

The general changes in the percentage of total sugars as found in the samples of total dry weight, leaf sheaths, and elongating cane are shown in Fig. 10. The total

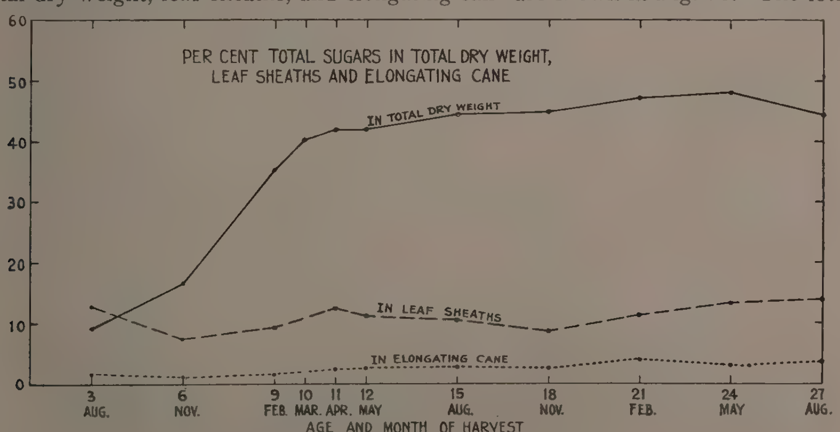

Fig. 10.

dry weight picture is one that is clearly dominated by per cent sucrose, which we have just discussed. The changes in the total sugar content of the leaf sheaths and of the elongating cane are very minor ones, and as we would expect to find in this most active growth region, there are no significant differences in the total sugar concentration in these parts of the plant as the cane crop increases in age. There may, however, be an indication of a seasonal effect from the leaf-sheath samples, which show slightly higher per cent total sugars in the summer than during the winter.

The nitrogen effects on per cent total sugars were not identified in any of the measurements made at 3 months, but at 6 months they had positively influenced all three samples. These influences, however, were different ones as will be seen from the following summary: as the nitrogen applications were increased the total sugars were decreased in the total dry weight and elongating cane whereas in the leaf sheaths they were definitely increased.

Lbs. N applied	No. of plots	Per cent total sugars found at 6 months: In total dry weight	In elongating cane	In leaf sheaths
40	10	19.12	1.52	6.78
100	20	16.88 ns	1.35 ns	7.36
160	10	16.89 ns	1.31 ns	8.46 ns
220	5	14.61	1.26 ns	8.11 ns

ns=not significantly different.

At 9 months the per cent total sugars in the total dry weight samples showed highly significant effects of the different amounts of nitrogen already applied and similar (altho non-significant) trends were found in the elongating cane and leaf-sheath samples. The highest concentration was found in the cane which had received only 40 pounds of nitrogen at 1½ months, and this cane, although greatly superior in its development to that which had received no nitrogen, was not making the same rapid growth that the other nitrogen-fertilized canes were making; thus it was storing more of its sugars. The second highest concentration of total sugars in the total dry weight was in the cane which had received 100 pounds of nitrogen, and this in turn was higher than that from the still more heavily fertilized canes which had by now produced over 100 tons of total green weight per acre.

At 9 months we identified an interaction between "amounts" and "time" from the leaf-sheath samples. Thus the per cent total sugars were higher when the 100-pound total nitrogen application was completed at 4 than at 6 months, but for the 160 (and also possibly the 220) pounds total application, the higher concentration was found in the cane which received its final 60 pounds at 6 than at 4 months. This latter circumstance is difficult to rationalize and since it carries only moderate significance we record its occurrence and dismiss further comment.

In the leaf sheaths at 10, 11, and 12 months significant effects from the different amounts of nitrogen were found, with the higher per cent total sugars coming from the more liberally fertilized canes.

Lbs. N applied	Per cent total sugars in leaf sheaths: At 10 mos.	At 11 mos.	At 12 mos.
0	10.40 ns	11.56 ns	10.22 ns
40	10.39 ns	12.10 ns	..... ns
100	10.39 ns	12.14 ns	10.36 ns
160	11.54 ns	12.64 ns	11.86 ns
220	11.86 ns	13.41 ns	11.76 ns

ns=not significantly different.

A highly significant influence on the per cent total sugars in the elongating cane and a corresponding although not a significant effect in the total dry weight and leaf sheaths were measured from differences in the time of application at the 12-month harvest, with lower amounts being found when a 60-pound application of nitrogen had been made in the preceding month.

After 12 months, treatment effects on per cent total sugars in the elongating cane and leaf sheaths were not significant, but in the total dry-weight samples the nitrogen fertilizer has generally increased the concentration of total sugars, with a trend towards a higher percentage from the larger N applications.

Lbs. N applied	Per cent total sugars in total dry weight				
	At 15 mos.	At 18 mos.	At 21 mos.	At 24 mos.	At 27 mos.
0	44.67	42.85	45.75	46.49	41.97
100	43.89	44.88	47.03	47.92	44.59
160	44.40	45.10	47.23	48.61	44.85
220	45.62	45.64	47.23	48.57	45.04

Per Cent Total Nitrogen (Tables 12, 13, 14, 15, and 16 in Appendix):

Since the chief objective in this study was concerned with nitrogen effects, we have determined the per cent total N in samples of the total dry weight, crusher juices, leaf punches from the leaf blades, and in the entire leaf blades, and also the per cent amino N in the elongating cane. The general relationships between these five samples is shown in Fig. 11. The per cent N in the leaf punches, in the entire leaf blades, and in the total dry weight dropped off consistently as the crop age increased to about 15 months; thereafter the decreases were quite small. The varia-

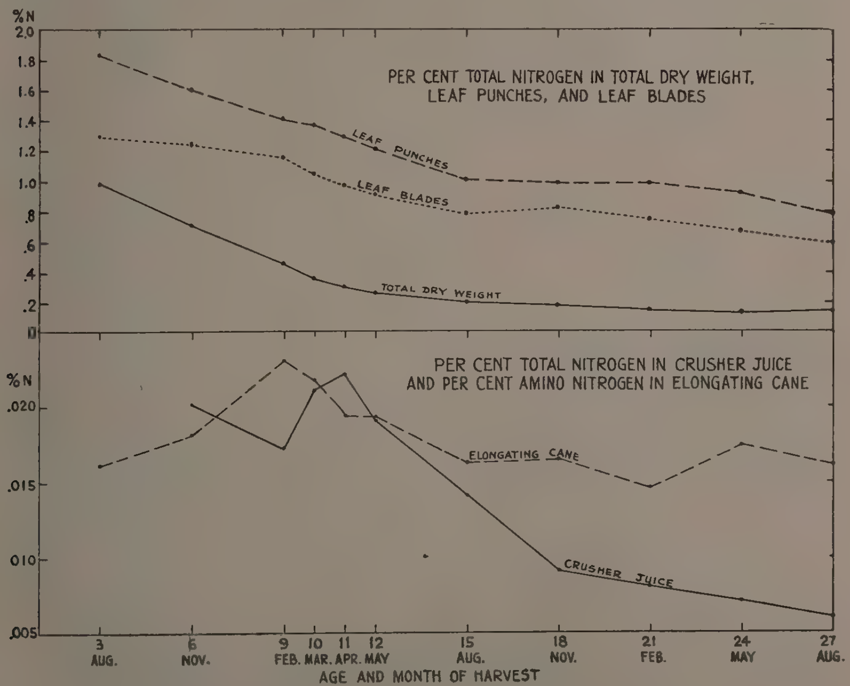

Fig. 11.

tions in the crusher juices in the harvests prior to 15 months are difficult to explain for they occurred regardless of the differences in the nitrogen treatments; their low amounts at 9 months coincide with a natural soil nitrogen content that was also low at this time, but since this soil N effect was not identified in the other plant samples, most likely it is just a coincidence. The higher amounts of amino nitrogen in the elongating cane at 9 months are quite likely a result from the nitrogen fertilizer applications that were made at 6 months; another increase after 21 months may be from the greatly increased soil nitrogen supply which became available by natural means at this time (see Fig. 2).

Specific effects from the various nitrogen treatments were definitely identified from any of the plant samples analyzed. These were mainly effects from the amounts applied and it can be said that with only a few exceptions each increase in the amount of nitrogen applied resulted in an increased concentration of nitrogen in the plant sample analyzed. This is adequately shown in Fig. 12 for the per cent

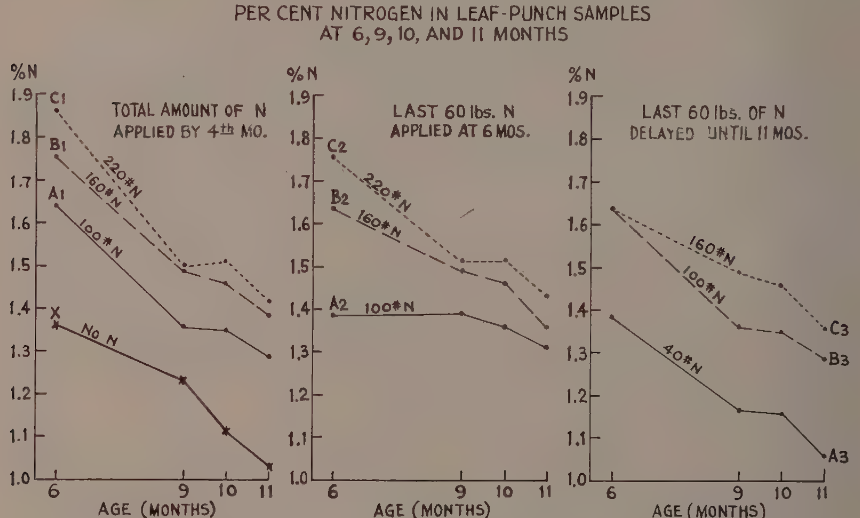

Fig. 12.

N in leaf-punch samples taken during the more critical growth stages at 6 to 11 months.

There were also a few instances in which the time of application had an effect. Thus at 10 months the crusher juices from cane fertilized at 1½ and 4 months had a significantly higher per cent N than that fertilized at 1½ and 6 months; the same trend (though not significant) was found in the total dry weight and in the elongating cane, but not in the leaf-punch or leaf-blade samples. At 12 months the concentrations of total nitrogen in the leaves were higher from the later applications, as was also the amino nitrogen in the elongating cane. At 15 months the late nitrogen application was still reflected in higher concentrations in all except the juice samples. At 21 months a significant interaction between "amounts" and "time" was identified from both the total dry weight and leaf-punch samples, *e.g.*, the effect from the increased nitrogen applications was not found when the total amounts had

been applied at 4 months but was quite definite when later applications were made.

It is from the samples taken during the first year of growth that we look for indices for guidance in nitrogen fertilization, since a correction for deficiency must be made at this time. Hence a study of the nitrogen data from the harvests at 6, 9, 10 and 11 months is of special interest, with special attention to Treatments A2 and B2 which eventually produced the most sugar from the 100 and 160 pounds N treatment respectively.

	Per cent N in total dry weight				Per cent N in leaf punches			
Treatment	At 6 mos.	At 9 mos.	At 10 mos.	At 11 mos.	At 6 mos.	At 9 mos.	At 10 mos.	At 11 mos.
A2—100 lbs.	.519	.402	.302	.262	1.38	1.39	1.36	1.32
B2—160 lbs.	.710	.498	.368	.316	1.64	1.49	1.47	1.36

	Per cent N in leaf blades				Per cent N in crusher juices			
Treatment	At 6 mos.	At 9 mos.	At 10 mos.	At 11 mos.	At 6 mos.	At 9 mos.	At 10 mos.	At 11 mos.
A2.........	1.05	1.15	1.02	.98	.010	.012	.014	.015
B2.........	1.26	1.23	1.14	1.02	.016	.021	.022	.028

	Per cent amino N in elongating cane			
Treatment	At 6 mos.	At 9 mos.	At 10 mos.	At 11 mos.
A2........	.0158	.0225	.0188	.0186
B2........	.0189	.0242	.0242	.0196

With the assumption that more sugar was produced at the optimum age of 21 months from 160 pounds of nitrogen (B2) than from 100 pounds (A2), it is most likely that the levels of per cent nitrogen that were found in the different samples taken from the crop of Treatment A2 represent early concentrations which are too low. For instance, the figures of .302 and .262 per cent N in the total dry weight at 10 and 11 months respectively, and the corresponding figures of 1.36 and 1.32 per cent N in the leaf-punch samples of Treatment A2 are believed to be low and to indicate that more than its 100 pounds of nitrogen was needed, because Treatment B2 which received 160 pounds of N outyielded A2. With similar reasoning, it would also appear that the corresponding N levels of .368 and .316 per cent N in the total dry weight, and 1.47 and 1.36 per cent N in the leaf-punch samples at 10 and 11 months, that were found in the samples from Treatment B2 are also too low, since when an additional 60 pounds application was given at 11 months the new N total of 220 pounds (Treatment C3) eventually produced more sugar than B2 (160 pounds). Thus we can temporarily set up the following N concentrations as critical or inadequate levels* in a crop of 32–8560 cane at the age of 11 months: .316 per cent total N in the total dry weight, 1.36 per cent in the leaf-punch samples, 1.02 per cent in the entire leaf blades, .028 per cent in the crusher juice and .0196 per cent amino N in the elongating cane. Unfortunately from the experiment as planned, we were unable to identify the desired *adequate* levels for per cent N in these crop samples.

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*Critical levels at 10½ months that were believed to be indicated in Waipio Experiment 108 ATN were as follows:

	Per cent N		
	In total dry weight	In leaf punches	In crusher juices
Plant crop	.335	1.36	.018
1st ratoon	.374	1.38	.033

The Primary Index

The data that have been collected from this experiment have afforded an opportunity to study the "primary index"* which has been suggested by Clements as a critical factor to be watched and regulated by adjustments in fertilization and irrigation to give a desired type of growth at different periods in the crop's development.

Our chief interest in this feature lies in the measurements which were made prior to that crop stage when we would still be able, if necessary, to correct a reliably established deficiency in nitrogen. Thus we are especially interested in the figures obtained from the harvests at 6, 9, 10, and 11 months. The primary indices, *i.e.*, percentages of total sugars in the leaf sheaths, have been obtained from each of 5 replicated plots of all treatments. In addition, the percentages of moisture in the same sheaths, and the percentages of total nitrogen in leaf-punch samples from the leaf blades have been secured. The averaged data for all harvests are given in Appendix Tables 11, 3, and 13, and in Fig. 13 we have plotted those parts which we especially wish to study more closely. Before we discuss Fig. 13, however, it is well to study Table III which is presented to show the extent of the variations in the primary index which were found in the early samplings, and the changes that occurred between the 6th and 11th months.

Looking at Table III we note two groups of 10 replicated plots each; both of these groups had received 100 pounds of N within 4 months and Group 2 received an additional 60 pounds of N (to make a total of 160 pounds) at 6 months. Thus at the age of 6 months, all 20 of the plots listed were actually replicates, and among these 20 plots we note a range in the variation of per cent total sugars in sheaths of from 6.291 to 9.488, with the average for each group of 10 plots being almost identical.

At the three subsequent harvests, the following ranges in the sugar-index variations between replicates that were found should give a good idea of the variability to be expected in these leaf-sheath samples:

(*a*) In the 100 pounds N group: a low of 8.467 and a high of 11.004 at 9 months; a low of 9.771 and a high of 11.723 at 10 months; and corresponding figures of 11.214 and 14.231 at 11 months.

(*b*) In the 160 pounds N group: low and high figures respectively at 9, 10, and 11 months, of 8.346 to 11.026; of 10.477 to 12.922; and of 9.951 to 15.632.

Of interest also is the fact that the average per cent total sugars in the leaf sheaths at 9 months was not significantly different for the two groups, although the second group had received an additional 60 pounds of nitrogen only 3 months previous. The averages for the two groups were also quite similar at 11 months. Hence it would be difficult to imply from these averages that lower sugar indices had resulted from the higher nitrogen applications. Moreover the total average change in this index found between 6 and 11 months was +5.408 for the cane which received 100 pounds of N and +5.113 for that which had received 160 pounds, clearly not a difference which is the proved effect of the nitrogen applications, although this

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*Clements, Harry F., and Kubota, K., 1943. The primary index, its meaning and application to crop management with special reference to sugar cane. The Hawaiian Planters' Record, 47: 257–297.

TABLE III

VARIATION IN THE PRIMARY INDEX (% TOTAL SUGARS IN LEAF SHEATHS) FROM 2 GROUPS OF REPLICATED PLOTS

Group 1

Pounds N applied	Plot no.	At 6 mos.	At 9 mos.	At 10 mos.	At 11 mos.	Average sugar index at 11 mos. (5 plots)
	36	6.955	9.029	10.134	12.458	
	10	7.286	10.112	11.723	12.408	
	24	7.558	8.570	10.020	13.885	13.166 (A1)
	20	7.811	9.760	10.334	13.132	
40+60+0=100..........	42	7.946	11.004	10.942	13.946	
	27	6.291	9.095	9.864	11.400	
	34	6.621	8.467	9.771	14.231	
	47	6.762	10.576	10.881	13.130	12.314 (B3)
	11	8.022	9.571	9.795	11.214	
	4	8.067	10.805	10.807	11.596	
100 lbs. N-group average		7.332	9.699	10.427	12.740	

Group 2

Pounds N applied	Plot no.	At 6 mos.	At 9 mos.	At 10 mos.	At 11 mos.	Average sugar index at 11 mos. (5 plots)
	15	6.968	9.651	10.516	11.073	
	8	7.087	11.026	11.812	12.688	
	23	7.372	8.346	10.494	9.951	12.337 (B2)
	50	7.395	9.538	12.922	15.632	
40+60+60=160..........	31	7.545	9.310	10.477	12.341	
	43	6.532	9.745	10.968	13.417	
	40	6.727	9.293	12.731	14.460	
	17	7.339	8.620	10.659	10.409	12.666 (C3)
	26	7.441	9.351	10.813	11.857	
	1	9.488	9.720	10.784	13.189	
160 lbs. N-group average		7.389	9.460	11.218	12.502	

Note: Note the following adjacent plots which had received different nitrogen totals:

100 lbs. N *vs.* 160 lbs. N

Plot No. 24 *vs.* No. 23
Plot No. 27 *vs.* No. 26
Plot No. 36 *vs.* No. 31
Plot No. 42 *vs.* No. 43
Plots No. 20 and 10 *vs.* No. 15

160-pound group had produced 8.6 tons of cane more than the 100-pound group at 11 months. (*Note:* This 60-pound N differential had then been effective for only 5 months.) Furthermore, after the harvest at 11 months, another nitrogen differential was made within each of these two groups; *i.e.,* the first 5 plots listed in each group received no more nitrogen whereas the last 5 were given another 60 pounds. The averaged sugar indices for these four sub-groups (now identified as Treatments A1, B3, B2, and C3) at 11 months (before this additional nitrogen was actually given) show very slight and non-significant differences. If their relatively high amounts for cane at this age do indicate a need for more nitrogen fertilizer, such a need was not quantitatively suggested, for contrary to the "law of diminishing returns" there were eventually more gains in sugar (T.S.A.) made from the 60 pounds added for Treatment C3 in Group 2 which had already received 160 pounds

of N, than from the same amount added for Treatment B3 in Group 1 which had received only 100 pounds.

Average sugar index at 11 months	Treat-ment	Total N applied	Tons sugar per acre At 15 mos.	At 18 mos.	At 21 mos.	At 24 mos.	At 27 mos.	Avg. gain (5 harvests)
13.166	A1	100 lbs.	10.6	12.6	10.3	11.4	8.3	
12.314	B3	160 lbs.	10.2	13.2	14.2	13.6	10.2	
Gain for B3 over A1..........			—.4	+.6	+3.9*	+2.2	+1.9	+1.6
12.337	B2	160 lbs.	11.4	14.2	16.0	11.1	8.7	
12.666	C3	220 lbs.	13.3	15.3	16.9	15.6	10.9	
Gain for C3 over B2..........			+1.9*	+1.1	+.9	+4.5*	+2.2	+2.1

*Significant gain.

In Fig. 13 we have arranged one series of graphs in which the total nitrogen applications as indicated were all on the field by 4 months, and a second series in which the total amounts indicated were completed with a 60-pound application at 6 months. Both the per cent total sugars (primary indices) and per cent moisture in the leaf-sheath samples (averages from 5 plots) are graphed for each series, from the samples taken at 6, 9, 10 and 11 months. From these graphs, one cannot help but get the impression that the higher nitrogen totals have been responsible for putting higher concentrations of total sugars in the leaf sheaths, and generally higher percentages of moisture also. And from Fig. 12 it has been noted already that the percentages of total nitrogen in the leaf-punch samples were also higher from those plots which have received the most nitrogen fertilizer. Thus a positive relationship was found between per cent total sugars in leaf sheaths, per cent moisture in leaf sheaths, and per cent total nitrogen in leaf-punch samples, each factor generally being increased as a result of the increased nitrogen applications. Moreover, at the same time, these increases were being accompanied by a greater crop growth, for at 11 months the following total dry weights were harvested:

From Treatment X—14.4 tons	From Treatment A2—20.5 tons
A1—23.0 tons	B2—25.8 tons
B1—29.1 tons	C2—30.2 tons
C1—26.3 tons	

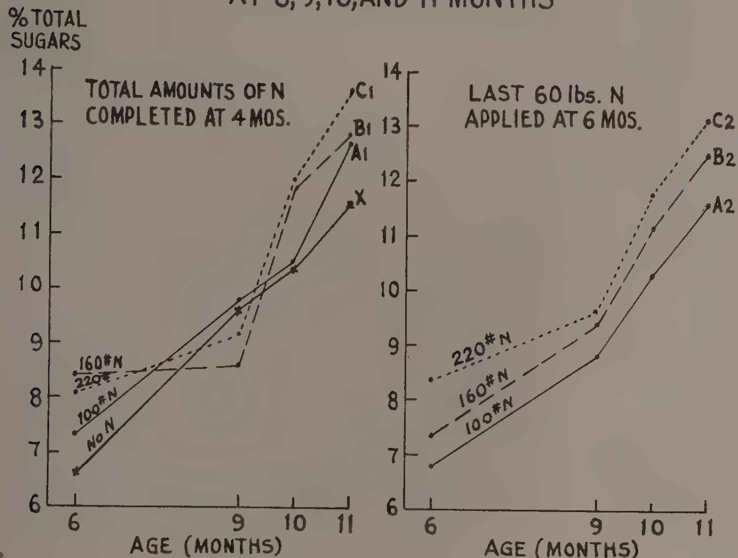
Min. diff. required=3.5 tons

Finally, the yields of commercial sugar obtained at the optimum age of harvest (21 months) were with one exception favorable to the higher applications of nitrogen; thus higher sugar yields eventually came from cane which at 11 months had shown us a higher per cent total N in its leaf-punch samples and a higher percentage of total sugars in its leaf sheaths.

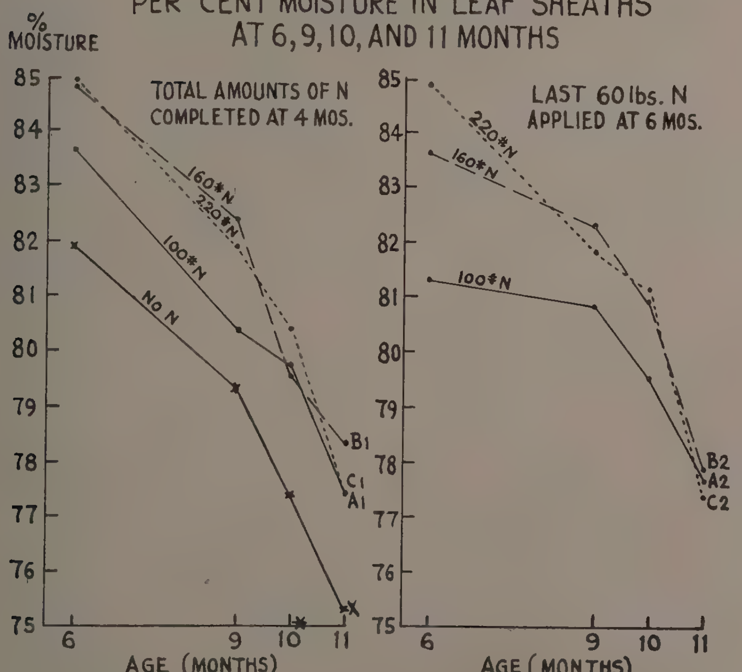
T.S.A. at 21 months		
Treatment X— 6.5 tons	Treatment A2—14.5 tons	Treatment A3—11.6 tons
A1—10.3 tons	B2—16.0 tons	B3—14.2 tons
B1—13.0 tons	C2—13.6 tons	C3—16.9 tons
C1—15.8 tons		

With such findings as these, we shall have difficulty in interpreting the sugar index for the kind of guidance we need in specific nitrogen fertilization.

PER CENT TOTAL SUGARS IN LEAF SHEATHS
AT 6, 9, 10, AND 11 MONTHS



PER CENT MOISTURE IN LEAF SHEATHS
AT 6, 9, 10, AND 11 MONTHS



* Note: 2.2 inches of rain fell in the 24 hours
preceding the harvest at 10 months

Fig. 13.

Yields

Yields of Total Green Weight, Dry Weight, and Millable Cane (Tables 17, 18, and 19 in Appendix):

The general nature of the development of this 32–8560 cane crop is shown in Fig. 14. Noteworthy are the facts that: (1) the most rapid increase in total green weight occurred between 3 and 6 months (August-November) and the rate of increase between 6 and 9 months (November to February) was only about half as much as in the three months previous; (2) from 9 to 12 months (February to May) the increase was the lowest of any 3-month period; (3) a constant rate of increase was maintained from 12 to 18 months (May to November); and (4) after 18 months there were actual losses in total green weight which appear to have become greater with more advanced age. Thus although seasonal effects are partial causes of these differences, the age effects are even more causative, *e.g.,* the 49-ton increase at 3–6 months during the first August-November season was three times that made at 15–18 months during the second August-November season, and whereas gains were made at 6–9 months during the first November to February there were losses recorded for these same months of the following year when the crop was 18–21 months old.

INCREASES OR LOSSES IN TOTAL GREEN WEIGHT (TONS PER ACRE)

May-Aug. 0–3 months	Aug.-Nov. 3–6 months	Nov.-Feb. 6–9 months	Feb.-May 9–12 months	May-Aug. 12–15 months	Aug.-Nov. 15–18 months	Nov.-Feb. 18–21 months	Feb.-May 21–24 months	May-Aug. 24–27 months
+10.5	+49.2	+26.1	+7.6	+15.9	+16.2	—8.6	—12.6	—13.2

Since these differences in total green weight are influenced by differences in moisture content, a more accurate idea of the crop development is obtained from a study of the increases in the total dry weights.

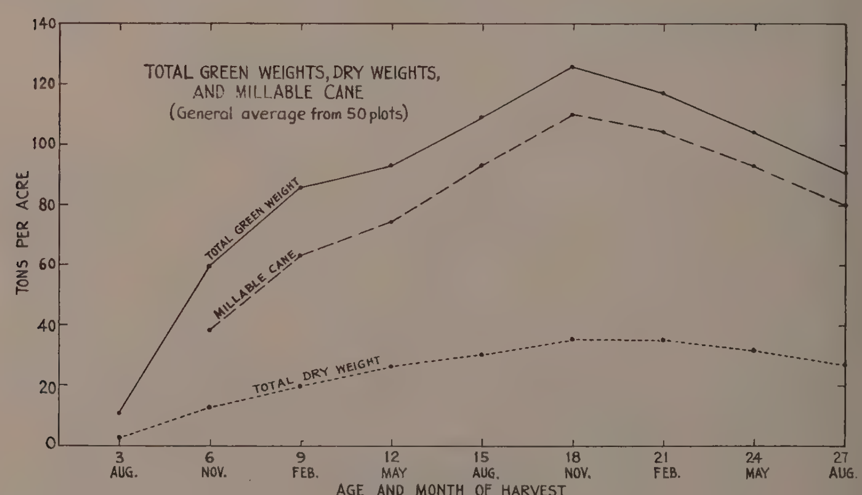


Fig. 14.

INCREASES OR LOSSES IN TOTAL DRY WEIGHT (TONS/ACRE)

May-Aug. 0–3 months	Aug.-Nov. 3–6 months	Nov.-Feb. 6–9 months	Feb.-May 9–12 months	May-Aug. 12–15 months	Aug.-Nov. 15–18 months	Nov.-Feb. 18–21 months	Feb.-May 21–24 months	May-Aug. 24–27 months
+2.00	+10.10	+7.83	+6.36	+4.31	+5.05	—.18	—3.49	—4.0

Here we note: (1) that the increase in dry weight in the months of August-November was twice as great for 3–6 months cane as for a crop 15–18 months old; and (2) that although gains were registered between the November-February and the February-May growth periods when the crop was 6–9 and 9–12 months old, actual losses in total dry weight took place in the corresponding months when the crop was 18–21, and 21–24 months old.

Millable cane weights followed quite closely the total green weights. Their rate of increase was fairly constant between 6 and 18 months, but a high mortality of the primary stalks and some death of suckers after 18 months produced a sharp drop in millable cane weights.

The influence of the different amounts of nitrogen upon the yields of the green and dry weights and millable cane was very similar, *i.e.,* these yields were increased when more than 100 pounds of nitrogen were applied and in general they were further increased by 220 pounds over 160.

The time of application had an effect upon these yields, especially at the harvest at 12 months, when yields were lower when the last nitrogen applications had only recently (at 11 months) been applied. At several other harvests an interaction between "time" and "amounts" was found. For instance, the cane harvested at 9 months which had received its total of 100 pounds of N by 4 months gave higher yields than when the last 60 pounds of this total were given at 6 months. However, cane which was to receive a total of 160 (or of 220 pounds) did not produce significantly more (or less) when its final 60 pounds were given at 4 than at 6 months. Again, at 11 months, the withholding from the 4th to the 6th month of the final 60 pounds applications for both the 100- and the 160-pound treatments gave poorer yields, but from the 220-pound treatment, there was an advantage gained when the last 60-pound application was made at 6 months.

At 15 months, the interactions are quite specific. In the 100-pound treatment, lower yields resulted when the total amount had not been applied by the 4th month. For the 160-pound treatment, the time of applying the final 60 pounds had no differential effect on the yields, but with the 200-pound total, there was a good gain secured when the final 60 pounds were given at 11 months than when this larger total application was completed earlier (either at 4 or at 6 months).

The interactions recorded from the 18-month harvest are as follows: (1) poorer yields from 100 pounds of nitrogen when its application *had not* been completed by 4 months; (2) poorer yields from 160 pounds when its application *had* been completed at 4 months; and (3) the best yields from the 220-pound treatment when its final 60 pounds was given at 11 months; furthermore a better yield when it was given at 6 than at 4 months. Apparently the large amounts (120 and 180 pounds) that were applied at 4 months in September were not too efficient.

The harvest at 21 months shows a slightly different pattern of effects from the interactions. The character of the stalk population had now changed and many primary stalks were dying off. From the 100-pound total we obtained higher yields

when the final 60 pounds of N was given at 6 months than at either 4 or 11 months. The 160-pound total also gave a higher yield when the final 60 pounds was given at 6 than at 4 and possibly also at 11 months. However, from the 220-pound total, the yields were higher when the final 60 pounds went on at 11 than at 6 months, although the yields from this 220 pounds completed at 4 months were now not significantly below this same amount completed at 11 months.

Yield Per Cent Cane (Table 20 in Appendix):

During the first year's growth, cane quality as measured by yield per cent cane was definitely and dominantly influenced by the amounts of nitrogen which had been applied, with poorer quality resulting from each increase in nitrogen. In general, the quality improved progressively with increased age between 18 and 24 months (November to May) but at 27 months it had deteriorated badly and was then no better than it had been at 12 months.

Lbs. N applied	Average yield per cent cane at progressive harvests								
	At 9 mos.	At 10 mos.	At 11 mos.	At 12 mos.	At 15 mos.	At 18 mos.	At 21 mos.	At 24 mos.	At 27 mos.
0..........	8.6	10.5	12.7	12.1	11.6	10.7	12.5	12.7	10.8
40..........	9.9	10.9	12.8	....	....	....	....	....	....
100..........	8.2	9.4	11.7	11.7	11.0	11.3	13.1	13.2	11.4
160..........	6.9	8.7	11.1	11.5	10.9	10.6	12.7	13.1	11.4
220..........	6.6	8.0	11.0	11.0	10.8	10.7	12.5	13.1	11.4

At 15 months, the first influence on the Y%C from differences in the time of applying the nitrogen fertilizer was found, with the best quality coming when the total nitrogen had all been supplied by the 4th month, and the poorest quality when the final 60-pound application was held off until 11 months. At the 18 months harvest an interaction is suggested between "amounts" and "time," with a poorer quality for the two higher totals (220 and 160 pounds) than for the low amount (100 pounds) occurring when the final 60-pound application was given at 6 or 11 months, but not when these same totals were completed at 4 months.

YIELD PER CENT CANE

Harvested at 21 months

Total lbs. N applied	Last 60 pounds at		
	4 mos.	6 mos.	11 mos.
100	12.4	13.4	13.4
160	12.6	12.8	12.7
220	12.8	12.0	12.8

Min. diff. required=.7

Harvested at 24 months

Total lbs. N applied	Last 60 pounds at		
	4 mos.	6 mos.	11 mos.
100	12.9	13.6	13.2
160	13.2	12.8	13.3
220	13.2	12.4	13.5

Min. diff. required=.7

At 21 and also at 24 months, an evidence of interaction is still present, *e.g.*, although the detrimental effect from increased amounts of nitrogen upon the Y%C was as expected when the total amounts were completed at 6 months, this same effect was not as clearly identified when the totals were completed at 11 months, and it even appears to be a favorable effect when the total applications were all given by the 4th month. These results may point to a seasonal effect since it was chiefly from the November applications (at 6 mos.) that the expected detrimental effects on cane quality were definitely found to accompany the increased total amounts of nitrogen applied.

Yields of Reducing Sugars, Sucrose, Total Sugars and Commercial Sugars (Tables 21, 22, 23, and 24 in Appendix):

The relationship between the acre yields of sucrose, total sugars, and commercial sugar is shown in Fig. 15. (The reducing sugar yields are not plotted but are given in Table 21 in the Appendix.)

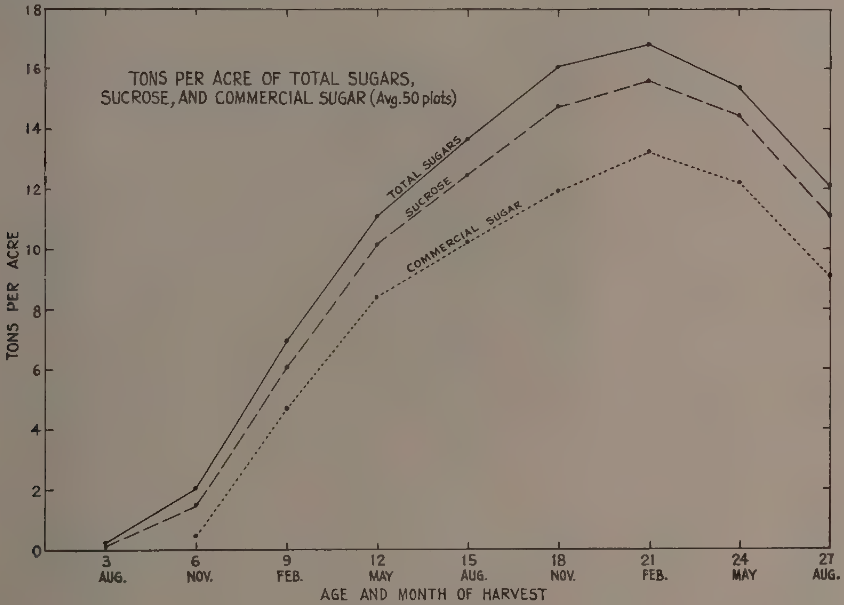


Fig. 15.

The reason for the increased spread noted between the lines for commercial sugars and sucrose, as the age of the crop increased, has not been ascertained. The most rapid increases took place between 6 to 9 and 9 to 12 months (November to May in this experiment) and in this respect they follow slightly behind and show a good relation with the corresponding increases in total dry weight. The actual losses found after 21 months are most likely age effects since there is good evidence that sunlight and temperature and soil moisture and nutrients were not deficient during the subsequent 6 months.

INCREASES OR LOSSES IN TOTAL TONS SUCROSE AND COMMERCIAL SUGAR PER ACRE

	0–3 mos.	3–6 mos.	6–9 mos.	9–12 mos.	12–15 mos.	15–18 mos.	18–21 mos.	21–24 mos.	24–27 mos.
Sucrose	+.11	+1.30	+4.66	+4.06	+2.32	+2.24	+ .90	−1.22	−3.26
Comm. sugar	...	+ .5	+4.2	+3.7	+1.8	+1.7	+1.3	−1.0	−3.1

The specific effects of the different nitrogen treatments are largely those from the different amounts applied, but there is again some evidence of the effect of the time of application and also of an interaction between these two factors.

At the age of 3 months, total sugars were higher in the cane which had received 40 pounds of N than in the controls which got no nitrogen. At 6 months, the 160-

pound application of N completed at 4 months had produced the most total sugars. In both instances, higher reducing sugars were largely responsible.

Yields at 9 months showed increases in reducing sugars, sucrose, and total sugars which paralleled the increased nitrogen applications. The commercial sugar at this early stage showed increases for 40 pounds over no N, and a further increase for the larger amounts, but apparently no real differences from either the 100-, 160-, or 220-pound applications. Also at this time, except for reducing sugars, the other yields were generally higher when the fertilization had been completed at 4 rather than at 6 months.

At the next three harvests at 10, 11 and 12 months (see Table IV), the higher

TABLE IV

EARLY YIELDS PER ACRE

Lbs. N applied	Tons/acre at 9 months: Red. sugar	Sucrose	Total sugar	Comm. sugar	Tons/acre at 10 months: Red. sugar	Sucrose	Total sugar	Comm. sugar
0..........	.23	3.51	3.93	2.8	.16	4.58	4.98	3.7
40..........	.32	5.25	5.85	4.4	.20	5.82	6.30	4.9
100..........	.54	6.36	7.23	5.1	.40	7.20	8.08	5.9
160..........	.73	6.75	7.83	5.2	.62	8.12	9.15	6.7
220..........	.85	6.81	8.02	5.1	.69	7.67	8.76	6.1

Lbs. N applied	Tons/acre at 11 months: Red. sugar	Sucrose	Total sugar	Comm. sugar	Tons/acre at 12 months: Red. sugar	Sucrose	Total sugar	Comm. sugar
0..........	.15	5.32	5.75	4.9	.19	6.19	6.71	5.1
40..........	.15	6.60	7.08	5.7	...	....	....	...
100..........	.26	8.39	9.03	7.3	.31	8.92	9.70	7.6
160..........	.41	10.63	11.61	9.0	.41	11.50	12.52	9.5
220..........	.47	10.90	11.94	9.2	.52	11.27	12.38	9.4

yields of all these sugars came from the higher applications of nitrogen, with the optimum probably indicated at 160 pounds. At 11 months, a significant interaction was found, with a differential effect from amounts being influenced by the time of application, as follows: when completed at 4 months, both the 100- and the 160-pound nitrogen totals gave superior yields to their completion at 6 months, but with the 220-pound treatment, its completion at 6 months produced better sugar yields than at 4 months. An independent effect of time was measured at 12 months, with the lower yields resulting when the last N applications had been held off until 11 months. In the harvests after 12 months, we find a rather general interaction between "amounts" and "time." This can best be studied and discussed from the accompanying 3 x 3 Interaction tables (Table V) showing the commercial sugar yields obtained in the last six harvests. (Similar tables for sucrose and total sugar yields will show similar trends.)

From Table V we can pick out several interesting points: (1) From a total application of 100 pounds of nitrogen (A) the highest sugar yields at 12, 15, and 18 months were obtained when this total amount was applied by the 4th month (A1), but after 18 months, better yields came when this N total was not completed until the 6th month of growth. Lower yields resulted, except at 21 and 27 months, when the second application of 60 pounds was held off until 11 months. (2) When 160 pounds of nitrogen were supplied for the crop, the best sugar yields through the 21-month harvest came apparently when this total was completed at the 6th month (B2) rather than earlier at 4 or later at 11 months. (3) From a total 220-pound

TABLE V

INTERACTIONS

Commercial Sugar Yields (TSA) Obtained at Different Ages from 3 "Amounts" and 3 "Times" of Application

Amounts:		Time:	
	A—100 lbs. N		1—Completed at 4 months
	B—160 lbs. N		2—Last 60 lbs. at 6 months
	C—220 lbs. N		3—Last 60 lbs. at 11 months

At 12 months

Amts.	Time 1	2	3	Amts. avg.
A......	8.9	7.4	6.4	7.6
B......	9.6	10.1	8.8	9.5
C......	9.9	9.9	8.4	9.4
	Time average			Gen. avg.
	9.5	9.1	7.9	8.8

At 15 months

Amts.	Time 1	2	3	Amts. avg.
A......	10.6	9.2	7.6	9.1
B......	11.6	11.4	10.2	11.1
C......	12.0	10.3	13.3	11.9
	Time average			Gen. avg.
	11.4	10.3	10.4	10.7

At 18 months

Amts.	Time 1	2	3	Amts. avg.
A......	12.6	11.0	10.4	11.3
B......	11.8	14.2	13.2	13.1
C......	11.5	12.8	15.3	13.2
	Time average			Gen. avg.
	12.0	12.7	13.0	12.5

At 21 months

Amts.	Time 1	2	3	Amts. avg.
A......	10.3	14.5	11.6	12.1
B......	13.0	16.0	14.2	14.4
C......	15.8	13.6	16.9	15.4
	Time average			Gen. avg.
	13.0	14.7	14.2	14.0

At 24 months

Amts.	Time 1	2	3	Amts. avg.
A......	11.4	11.6	10.4	11.1
B......	14.0	11.1	13.6	12.9
C......	13.5	14.0	15.6	14.4
	Time average			Gen. avg.
	13.0	12.2	13.2	12.8

At 27 months

Amts.	Time 1	2	3	Amts. avg.
A......	8.3	10.2	8.9	9.1
B......	9.5	8.7	10.2	9.5
C......	10.4	8.8	10.9	10.0
	Time average			Gen. avg.
	9.4	9.2	10.0	9.5

application, Treatment C3 in which this total was given in 4 doses with the final 60 pounds at 11 months proved the better sugar producer for all harvests after 12 months. (4) When the total amounts were given in only 2 applications, at 1½ and at 4 months, both C1 (220 pounds) and B1 (160 pounds) were superior to A1 (100 pounds) at all harvests except that at 18 months. (5) When the last 60 pounds of nitrogen for each N total were held until the 6th month, Treatment B2 (160 pounds) was the best sugar producer at 12, 15, 18, and 21 months but perhaps fell behind at 24 and 27 months. (6) When a final 60 pounds of N was applied at 11 months Treatment C3 (220 pounds) was consistently best after the harvest at 12 months when it was slightly below B3 (160 pounds). (7) The best results from 100, 160, and 220 pounds of N came when they were applied as follows:

Nitrogen totals used	Treatment	Age when applied: At 1½ mos.	At 4 mos.	At 6 mos.	At 11 mos.	Results T.S.A. at 21 mos.
100 lbs.........	A2	40 lbs.	0	60 lbs.	0	14.5
160 lbs.........	B2	40 lbs.	60 lbs.	60 lbs.	0	16.0
220 lbs.........	C3	40 lbs.	60 lbs.	60 lbs.	60 lbs.	16.9

(8) The highest commercial sugar yields were obtained from the harvest at 21 months. Actual yields at 24 months were not significantly better than those at 18 months—they most certainly showed lower rates of sugar produced per acre per

month; and when the harvesting was delayed until 27 months, the total sugar yields were less than they had been at 15 months.

Treatment C3 at 21 months had produced more commercial sugar than Treatment B2, but since the differences between them are not statistically significant, we are inclined to credit C3 with only slight superiority—not quantitatively established.

COMPARISONS OF TREATMENTS C3 AND B2 AT 21 MONTHS

Yields	C3	B2	Composition	C3	B2
Tons green weight	149.1	140.4	% red. sugars	1.044	.884
Tons dry weight	44.40	43.42	% sucrose	43.75	43.81
Tons millable cane	132.4	125.6	% total sugars	47.20	47.00
Tons commercial sugar..	16.9	16.0	Yield % cane	12.8	12.8

The relative performances as measured by tons sugar per acre per month (Table VI) fell off for all treatments after 21 months. Prior to this time we note the excellent results from Treatment C3 at 15 and 18 months, and from several other treatments as early as 12 months. From a total of 100 pounds of N (Treatment A), its complete application by 4 months (A1) gave its most efficient utilization. From a 160-pound total (Treatment B), completion at 6 months (B2) was superior to an earlier completion at 4, or to a later completion at 11 months. And the best results from 220 pounds (Treatment C) were when it was split up for 4 applications with a final 60 pounds being given at 11 months (C3).

TABLE VI

TONS SUGAR PER ACRE PER MONTH

Treatment	When harvested					
	12 mos.	15 mos.	18 mos.	21 mos.	24 mos.	27 mos.
A1..........	.74	.71	.70	.49	.48	.31
A2..........	.62	.61	.61	.69	.48	.38
A3..........	.53	.51	.58	.55	.43	.33
B1..........	.80	.77	.66	.62	.58	.35
B2..........	.84	.76	.79	.76	.46	.32
B3..........	.73	.68	.73	.68	.56	.38
C1..........	.83	.80	.64	.75	.56	.39
C2..........	.83	.69	.71	.65	.58	.33
C3..........	.70	.89	.85	.80	.65	.40

The excellent performances of this cane at the age of only 12 months need further emphasis and should not go unnoticed, especially those made by Treatments B2, C1, C2, and B1 which had received their 160 or 220 pounds of nitrogen by their sixth month of growth.

Treatment	Total lbs. N/ac.	Yields harvested at 12 months			
		TSAM	TCA	Y%C	TSA
B2............	160	.84	87.1	11.5	10.1
C1............	220	.83	88.4	11.2	9.9
C2............	220	.83	88.0	11.2	9.9
B1............	160	.80	84.9	11.4	9.6
A1............	100	.74	75.4	11.8	8.9
A2............	100	.62	65.5	11.3	7.4
Min. diff. req.			9.8	ns	1.3

In spite of the fact that: (*a*) these larger amounts of nitrogen are usually considered excessive for a crop to be cut at 12 months, (*b*) both Treatments B2 and C2 were given an application of nitrogen as late as six months before this harvest,

and (*c*) no drying-off period was given before harvesting this cane, it will be seen that the quality (Y%C) was not significantly poorer than that from cane which had received a lesser amount of nitrogen. It is quite clear that the larger nitrogen applications have in this case produced more cane and sugar. Apparently then, the harvest at 12 months was, as we have previously pointed out, from a stalk population that was at a very uniform state of maturity with but few dead stalks and suckers, and so the expected effect of high nitrogen in lowering juice quality was not found. If these things indicate that we can use these larger amounts of nitrogen (which will produce greater cane yields) without having them lower the juice quality, then perhaps we should give more consideration to harvesting at those ages when the stalk population is apt to be most constant.

Nitrogen Uptake

Pounds of Nitrogen Recovered (Table 25 in Appendix):

Without exception, the amounts of nitrogen that were recovered in the dry weights harvested were increased by each increase in nitrogen applied. The X plots which were given no nitrogen fertilizer had picked up as much as 112 pounds per acre at 6 months from the natural soil supply, but recoveries by this cane in subsequent harvests gradually fell off. The maximum recovery from 40 pounds of N applied at 6 weeks came from the harvest at 6 months, whereas from the higher applications the maximum recovery came 3 months later. Thereafter the recoveries from all treatments declined and at 27 months, the large differences which had been apparent in the first year had almost disappeared (Fig. 16).

An average of the amounts recovered from all harvests gives 58 pounds from the no-N treatment, and 104, 152, and 172 pounds from the 100, 160, and 220 pounds N treatments respectively. Deducting 58 pounds found in the "no-N" plots or controls from the amounts found in the different nitrogen-fertilized plots, the average recoveries of the amounts of N that were actually applied are respectively 46, 59, and 52 per cent from the 100-, 160-, and 220-pound treatments. Apparently a considerable amount of the nitrogen supplied has been left behind in the dead leaves and roots; its availability to subsequent cane crops is doubtful however, since it will be needed and used by the soil organisms in breaking down the highly carbonaceous plant material (the trash, stubble, and old roots) that it was originally responsible for making, and thereby maintaining the carbon: nitrogen balance in the field soil. The actual amounts recovered per acre per day are influenced by the amounts applied, but the rates of nitrogen uptake (indicated by Fig. 17) are seen to increase very fast during the first 6 months and thereafter to drop off sharply, whether or not the crop has received any nitrogen fertilizer, only a moderate amount, or a very large application.

Some Interesting Ratios

(1) Ratio of Per Cent Total Sugars to Per Cent N in Total Dry Weight:

Lbs. N applied	Per cent total sugar ÷ per cent N				
	At 3 mos.	At 6 mos.	At 9 mos.	At 10 mos.	At 11 mos.
40	9.4	36.8	127.7	174.3	217.0
100	...	23.8	92.1	132.5	159.4
160	...	20.1	67.4	101.0	128.2
220	...	15.4	60.6	85.2	115.3
Average	9.4	24.0	87.0	123.3	155.0

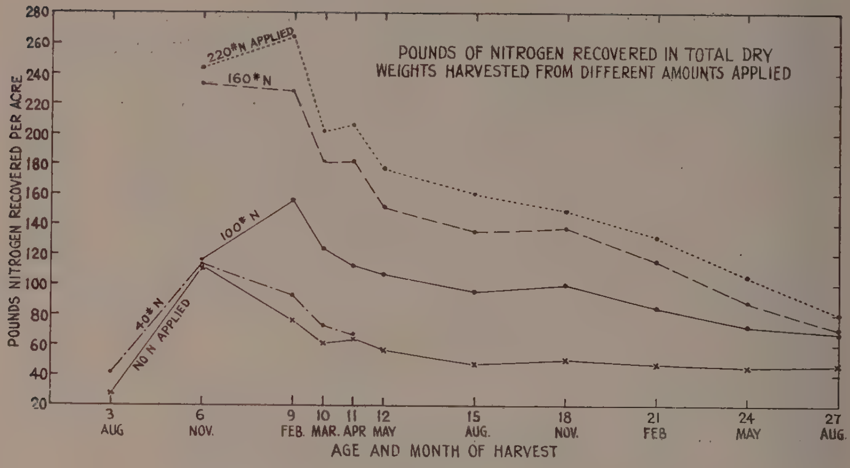


Fig. 16.

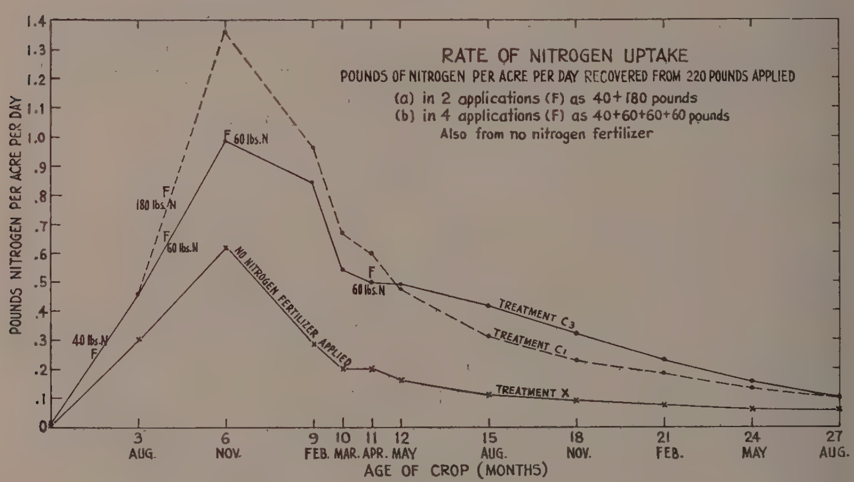


Fig. 17.

At the age of 3 months the concentration of sugars in the total dry weight was only 9.4 times the concentration of nitrogen. At 6 months this concentration of sugars averaged 24, and at 9 months 87 times that of nitrogen, with higher ratios than these averages coming from the smaller than from the larger amounts of nitrogen applied. Similarly at both 10 and 11 months (and in all subsequent harvests too) each added amount of nitrogen resulted in a decrease in this sugar-to-nitrogen ratio. At 11 months it would appear that a ratio of 128 (or higher) to 1 found associated with the 160 pounds N treatment indicated a sugar-to-nitrogen status that was too high for this crop age, and that more nitrogen fertilizer was called for, because when another 60 pounds of N was added to make a total application of 220 pounds, this addition eventually resulted in a higher recoverable sugar yield.

(2) Ratio of Pounds N Recovered to Pounds N Applied:

Available nitrogen: From soil	Applied in fertilizer	Lbs. N recovered ÷ lbs. N applied At 6 mos.	At 9 mos.	At 12 mos.	At 15 mos.	At 18 mos.	At 21 mos.	At 24 mos.
?	+ 40 lbs.	2.80	2.32	....	....	....	....	....
?	+ 100 lbs.	1.77	1.56	1.07	.96	1.00	.85	.73
?	+ 160 lbs.	1.46	1.42	.94	.85	.86	.72	.55
?	+ 220 lbs.	1.11	1.20	.80	.73	.68	.60	.48

The fact that these ratios are greater than 1 for the harvests at 6 and 9 months, suggests that a considerable additional amount of nitrogen must have been made available from the natural soil supplies.

The ratios which are seen to decrease with advancing age, indicate that a considerable amount of the natural and applied nitrogen is contained in the dead leaves, stalks, and roots which are left behind in the field. The fact that these ratios are larger when associated with the smaller nitrogen applications would indicate that the crops grown have drawn more heavily upon the soil nitrogen supply when the smaller amounts were supplied in the fertilizer; thus we would expect a somewhat greater depletion of the natural soil nitrogen supply, and conversely a conservation of the supply, that is dependent upon the amount of nitrogen fertilizer given.

If we deduct the amount of N found in the crops from the X plots (which received no N fertilizer) from the amounts found in the crops which did get nitrogen fertilizer, we have the following percentage recoveries from the fertilizer only.

Lbs. N applied	Per cent recovery of N applied in fertilizer only At 6 mos.	At 9 mos.	At 12 mos.	At 15 mos.	At 18 mos.	At 21 mos.	At 24 mos.
40............	2.7	38.7	....	....	....	....	....
100............	65.4	79.0	50.1	48.0	49.0	38.2	26.8
160............	75.8	94.4	58.8	54.3	54.3	42.8	26.6
220............	60.1	84.9	54.5	50.8	44.5	38.4	27.1

Apparently the greatest recovery from the applied fertilizer was found at 9 months, at the time when the crop had its maximum tonnage of green tops, and before there had been any great accumulation of dead leaves. Thereafter, the reduced N recoveries probably indicate losses of nitrogen to those parts of the crop which made up the field trash, and somewhere about 18 months these recoveries were actually less than half of the amounts applied. Although it is not entirely clear just what effect the nitrogen differentials have had upon the percentage recoveries it is worthy of note that the higher recoveries of the nitrogen applied did come from the cane which had received the 160 pounds total.

(3) Ratio of Pounds of N Recovered in Total Dry Weight to Tons of Millable Cane Harvested:

Treatments	Lbs. N applied	Pounds N recovered ÷ T.C.A. At 15 mos.	At 18 mos.	At 21 mos.	At 24 mos.
A..........	100	1.13	.99	.92	.86
B..........	160	1.33	1.12	1.02	.90
C..........	220	1.46	1.21	1.07	.95

Excluding the nitrogen left behind in the stubble, roots, and dry trash, these data show ratios which decrease with advancing age and are increased by each additional increment of nitrogen applied. However, it seems unlikely that more than 1½ pounds of N actually left the field in the total dry weight with each ton of millable

cane harvested after 12 months, and in fact this figure was not far from 1 pound N per T.C.A. from Treatment C at 21 months when it made its optimum sugar yield.

Indices of efficiency from the nitrogen fertilizer applied, when measured as (*a*) pounds of N per ton of cane (TCA), or (*b*) pounds of nitrogen per ton of sugar (TSA) were as follows:

	Treatment	Age at harvest 12 mos.	15 mos.	18 mos.	21 mos.	24 mos.	27 mos.
Lbs. N/TCA	A	1.54	1.21	0.99	1.08	1.19	1.26
	B	1.94	1.57	1.30	1.41	1.62	1.93
	C	2.57	2.01	1.77	1.79	1.99	2.52
Lbs. N/TSA	A	13.16	10.98	8.77	8.26	9.01	10.98
	B	16.84	14.41	12.21	11.11	12.40	16.84
	C	23.40	18.64	16.67	14.29	15.28	22.00

The highest efficiency is seen to be from Treatment A (100 pounds N applied) harvested at 18–21 months; this efficiency diminished as larger N applications were made. But Treatment C which proved to be the optimum producer of sugar at 21 months shows an efficiency at this age that is represented by 1.79 pounds N applied per ton of cane harvested, and by 14.29 lbs. N per ton of sugar. These figures are quite similar to those which were recently found in a study* of the best performance records from Grade A nitrogen experiments on plant crops—namely, 1.7 pounds N per ton of cane and 14.6 pounds N per ton of sugar.

(*4*) *Ratio of Per Cent Reducing Sugars to Per Cent Sucrose:*

Lbs. N applied	Per cent reducing sugars ÷ per cent sucrose At 6 mos.	At 9 mos.	At 10 mos.	At 11 mos.	At 12 mos.	At 15 mos.	At 18 mos.	At 21 mos.	At 24 mos.	At 27 mos.
0..........	.30	.07	.04	.028	.031	.042	.037	.020	.025	.048
40..........	.25	.06	.03	.022	....	....	....	....	....	....
100..........	.39	.09	.05	.031	.035	.044	.037	.019	.022	.036
160..........	.47	.11	.07	.039	.036	.047	.044	.020	.021	.037
220..........	.54	.13	.09	.043	.046	.048	.044	.021	.022	.039

Within the first year and a half, the influence from the different nitrogen applications upon the ratio of reducing sugars to sucrose was quite definite, but thereafter this nitrogen influence tended to disappear. Between 6 and 11 or 12 months this ratio declined, and a better cane quality resulted. Its increase between 11 and 15 months is associated with the increase in suckers that was found in this period. Its decrease after 15 months contributes one reason for the better cane quality noted thereafter, and its relatively higher amounts at 27 months are undoubtedly due to the high stalk mortality which was found at this advanced age.

(*5*) *Ratio of Tons Total Sugars to Tons Total Dry Weight:*

Lbs. N applied	Tons total sugar ÷ tons total dry weight At 3 mos.	At 6 mos.	At 9 mos.	At 10 mos.	At 11 mos.	At 12 mos.	At 15 mos.	At 18 mos.	At 21 mos.	At 24 mos.	At 27 mos.
0....	.09	.13	.35	.40	.40	.41	.45	.43	.46	.47	.42
40....	.09	.19	.37	.41	.43	...	...	...	...	...	...
100....	...	.17	.36	.40	.42	.42	.44	.45	.47	.48	.45
160....	...	.17	.34	.40	.42	.42	.44	.45	.48	.49	.45
220....	...	.15	.34	.39	.42	.42	.46	.46	.47	.49	.45

*Borden, R. J., 1944. Crop relationships with special reference to nitrogen efficiency. The Hawaiian Planters' Record, 48: 65–72.

Negligible differences in the ratios of total sugars to total dry weight were found between the nitrogen treatments. These ratios all increased quite rapidly for the first 10 months but more gradually thereafter until 24 months. At 21 months they were quite comparable with the average ratios which we obtained at 20½ months from both plant and first ratoons in our studies from Waipio Experiment 108 ATN.

It is quite likely that these increased ratios after 10 months are due to the fact that the total dry weights that we have recorded do not include the trash, and that if this field trash, which contains very little sugar, had actually been included as total dry weight, these ratios would have remained closer to that of .40 which was found at 10 months before much trash had accumulated. In other words, it is quite likely that the true ratio of sugars to dry weight remains fairly constant after the crop becomes approximately 10 months old.

(6) Ratio of Tons Reducing Sugars to Tons Total Dry Weight:

	Tons reducing sugar ÷ tons total dry weight										
Lbs. N applied	At 3 mos.	At 6 mos.	At 9 mos.	At 10 mos.	At 11 mos.	At 12 mos.	At 15 mos.	At 18 mos.	At 21 mos.	At 24 mos.	At 27 mos.
0....	.031	.029	.021	.013	.010	.011	.017	.015	.008	.011	.018
40....	.038	.037	.021	.013	.009	....	....	....	....	....	....
100....	....	.046	.027	.020	.012	.013	.017	.015	.008	.010	.014
160....	....	.052	.032	.027	.015	.014	.018	.018	.009	.009	.015
220....	....	.049	.036	.031	.017	.018	.020	.018	.009	.010	.015

These ratios of reducing sugars to total dry weight were definitely influenced by the amounts of nitrogen applied. Decreasing amounts during the first 11 or 12 months, increases at 15 and 18 months, the further decreases at 21 and 24 months, with still another increase at 27 months, are again the influence of the changes which were taking place in the stalk population and do not need further comment here.

(7) Ratio of Tons Sucrose to Tons Total Dry Weight:

	Tons sucrose ÷ tons total dry weight										
Lbs. N applied	At 3 mos.	At 6 mos.	At 9 mos.	At 10 mos.	At 11 mos.	At 12 mos.	At 15 mos.	At 18 mos.	At 21 mos.	At 24 mos.	At 27 mos.
0....	.06	.09	.32	.37	.37	.37	.41	.39	.43	.43	.38
40....	.05	.15	.34	.38	.40	....	...	...	...	....	...
100....	...	.12	.32	.36	.39	.39	.40	.41	.44	.45	.41
160....	...	.11	.29	.36	.39	.38	.40	.41	.44	.45	.41
220....	...	.09	.29	.34	.39	.38	.41	.42	.44	.45	.41

In contrast to the effects from the different nitrogen applications which increased the ratios of reducing sugars to total dry weights especially in the early harvests, the ratios of sucrose to total dry weight were only slightly reduced when the larger applications of nitrogen were made, and after 10 months the nitrogen effects on these ratios were very similar.

(8) Ratio of Tons Commercial Sugar to Tons Sucrose in Total Dry Weight:

	Tons commercial sugar ÷ tons sucrose									
Lbs. N applied	At 6 mos.	At 9 mos.	At 10 mos.	At 11 mos.	At 12 mos.	At 15 mos.	At 18 mos.	At 21 mos.	At 24 mos.	At 27 mos.
0..........	.61	.80	.81	.92	.82	.85	.82	.84	.86	.83
40..........	.57	.84	.84	.86	...	...	...	...	...	...
100..........	.27	.80	.82	.87	.85	.81	.82	.86	.85	.82
160..........	.19	.77	.83	.85	.83	.82	.81	.84	.84	.83
220..........	.16	.75	.80	.84	.83	.81	.80	.85	.87	.81

These ratios show in another way (1) the excellent recovery at the early age of

11 months of commercial sugar from the total sucrose which the crop has stored up; (2) the decrease in these recoveries at 15 and at 18 months; but (3) another good recovery at 21–24 months. They also show that the nitrogen effects are chiefly those found in the early growth stages before the applied nitrogen has been fully assimilated. Apparently the optimum amount of commercial sugar which can be made was approximately 85 per cent of the sucrose which was stored up by these crops.

(9) Ratio of Millable Cane to Total Green Weight:

Lbs. N applied	Tons millable cane ÷ tons total green weight At 6 mos.	At 9 mos.	At 10 mos.	At 11 mos.	At 12 mos.	At 15 mos.	At 18 mos.	At 21 mos.	At 24 mos.	At 27 mos.
0..........	.58	.72	.77	.78	.76	.84	.86	.88	.88	.84
40..........	.65	.73	.80	.80	...	...	...	...	...	...
100..........	.64	.72	.80	.81	.79	.85	.88	.89	.90	.87
160..........	.66	.75	.81	.82	.80	.86	.88	.89	.89	.88
220..........	.63	.75	.80	.81	.79	.86	.87	.89	.89	.88

It is very doubtful that the different amounts of nitrogen applied have had a significant effect on the ratios of millable cane to total green weight. All of the ratios increased up to 11 months, dropped off at 12 months, but at 15 months had again increased and reached their highest point to date; thereafter there were slight increases again until 21 or 24 months, followed by a slight decrease at 27 months. These facts would make it appear that the total green weight has contributed rather directly to the total amount of 32–8560 millable cane that was harvested.

Weather Relationships

Basic yield and associated weather data, which have been tabulated for nine successive growth periods of 3 months each, are given in Table VII. From these data Table VIII has been prepared to show the relative utilization or efficiency of the

TABLE VII

BASIC YIELD AND WEATHER DATA

Growth period	Dates	Age (mos.)	Increase in yield (tons/acre) (Average 15 plots Treatment C) Green wt.	Dry wt.	Total sugars	T.C.A.	T.S.A.
1..........	May 11-Aug. 11	0–3	10.6	2.00	.194	.....	....
2..........	Aug. 12-Nov. 10	3–6	56.3	10.94	1.908	42.87	0.31
3..........	Nov. 11-Feb. 9	6–9	35.7	9.80	5.649	33.09	4.67
4..........	Feb. 10-May 11	9–12	5.1	6.71	4.579	9.60	4.42
5..........	May 12-Aug. 10	12–15	19.9	5.54	3.625	23.81	2.44
6..........	Aug. 11-Nov. 9	15–18	14.1	4.87	2.219	14.24	1.37
7..........	Nov. 10-Feb. 8	18–21	—3.3	1.50	1.377	—0.50	2.23
8..........	Feb. 9-May 9	21–24	—14.9	—3.81	—1.745	—12.60	—1.07
9..........	May 10-Aug. 8	24–27	—24.0	—8.00	—4.415	—23.36	—4.35

WEATHER MEASUREMENTS

Growth period	Gram calories	Hours of sunshine	Day-degrees	Avg. temperature Max.	Min.	Range in temperature	Avg. Wind velocity (m.p.h.)
1...........	58,229	720	1430	85.4	70.7	14.7	6.12
2...........	48,923	657	1434	84.7	71.9	12.8	5.07
3...........	33,759	502	1044	81.5	66.5	15.0	4.29
4...........	50,279	644	956	80.5	64.2	16.3	5.80
5...........	60,569	689	1396	85.4	71.4	14.0	8.12
6...........	51,331	683	1499	85.5	70.4	15.1	6.31
7...........	36,338	554	1078	81.9	65.0	16.9	5.75
8...........	46,865	684	1045	81.5	64.9	16.6	5.55
9...........	63,204	898	1374	88.1	69.9	18.2	7.35

TABLE VIII

SUNLIGHT AND TEMPERATURE UTILIZATION BY TREATMENT C

220 Pounds of Nitrogen (Average of 15 Plots)

Growth period	Tons total green wt./ac. Per 1000 gm. cal.	Per 100 hrs. sun	Per 1000 day-degr.	Tons total dry wt./ac. Per 1000 gm. cal.	Per 100 hrs. sun	Per 1000 day-degr.	Tons total sugar/ac. Per 1000 gm. cal.	Per 100 hrs. sun	Per 1000 day-degr.
1	.182	1.472	7.413	.034	.278	1.399	.003	.027	.136
2	1.151	8.569	39.261	.224	1.665	7.629	.039	.290	1.331
3	1.057	7.112	34.195	.290	1.952	9.387	.167	1.125	5.411
4	.101	.792	5.335	.133	1.042	7.019	.091	.711	4.790
5	.329	2.888	14.255	.091	.804	3.968	.060	.526	2.597
6	.275	2.064	9.406	.095	.713	3.249	.043	.325	1.480
7	(loss)	(loss)	(loss)	.041	.271	1.391	.038	.249	1.277
8	(loss)	(loss)	(loss)	(loss)	(loss)	(loss)	(loss)	(loss)	(loss)
9	(loss)	(loss)	(loss)	(loss)	(loss)	(loss)	(loss)	(loss)	(loss)

Growth period	Tons millable cane/ac. Per 1000 gm. cal.	Per 100 hrs. sun	Per 1000 day-degr.	Tons comm. sugar/ac. Per 1000 gm. cal.	Per 100 hrs. sun	Per 1000 day-degr.
1	....	....	....	....	....	....
2	.876	6.525	29.895	.006	.047	.216
3	.980	6.592	31.695	.138	.930	4.473
4	.191	1.491	10.042	.088	.686	4.623
5	.393	3.456	17.056	.040	.354	1.748
6	.277	2.085	9.500	.027	.201	.914
7	(loss)	(loss)	(loss)	.061	.403	2.069
8	(loss)	(loss)	(loss)	(loss)	(loss)	(loss)
9	(loss)	(loss)	(loss)	(loss)	(loss)	(loss)

temperature and sunlight received by those 15 plots which received the total 220-pound nitrogen application.

Once again we note a considerable difference in the efficiency of gram calories of sunlight energy, hours of sunshine, and day-degrees, during the different growth or age periods. For instance: the highest total green weights per units of energy, hours of sunshine, or day-degrees were found in Period 2 when the crop was 3 to 6 months old between August and November, and these weights were four times similar weights obtained in the subsequent August to November period when the crop was 15 to 18 months old. The dry weights per unit of all three weather measurements were greatest during Period 3 (at 6–9 months in November-February) and these were seven times those secured in the following November-February period when the crop was 18 to 21 months old. Period 4 (February-May) shows higher total dry weights from each weather unit than Period 5 (May-August) although just the reverse was found for total green weights. Apparently these facts indicate interactions between the age and moisture content of the crop and these different weather measurements.

Sunlight and temperature had their greatest effect on the millable cane yield between 3 and 9 months (August to February). Both total sugars and commercial sugars produced per unit of weather measurement were highest in Periods 3 and 4 between November and May from a crop that was only 6 to 12 months old. The effectiveness of these elements of weather dropped sharply thereafter. Also apparent is the fact that during Periods 2 and 3 the utilization of equivalent amounts of sunlight energy, sunshine hours, and day-degrees was quite similar for cane yields but entirely different for sugar yields. All of these differences make it appear that

a careful study of the interactions between nitrogen fertilization, crop age, and weather effects should be most enlightening.

Summary

The contribution which the soil made to the total supply of available nitrogen varied from month to month, and although its actual amount is difficult to anticipate, it is a real factor that must be considered in studies of nitrogen effects on field-grown crops.

A large part of the well-recognized effect of nitrogen on cane quality is most likely a direct effect of the nitrogen on the stalk population. Both dead canes and suckers were involved, and these have influenced both the yields and the composition of the crop.

The maximum amount of leafy green tops which was found at 6 to 9 months suggests the possibility for maximum photosynthesis at this age. Nitrogen applications had a definite effect on the amount of this green top.

Moisture in the cane plant was increased when nitrogen applications were increased; and a similar effect was found on the percentage of reducing sugars.

The sucrose concentration increased rapidly between 6 and 11 months. It was lower in the more liberally nitrogen-fertilized crop of the first year's harvests but not significantly lower thereafter.

The effect of nitrogen on the percentages of total sugars was influenced by the age of the crop at harvest. In very young cane, the higher nitrogen produced a lower concentration but after 9 months a directly opposite effect was indicated.

Increased nitrogen applications were definitely reflected by the increased concentrations of nitrogen within the different crop or plant samples analyzed. Critical levels are suggested (but need further verification) for 32–8560 cane at 11 months of age as .316 per cent N in the total dry weight, 1.36 per cent N in the leaf punch samples, 1.02 per cent N in the entire leaf blades, .028 per cent N in the crusher juice, and .0196 per cent amino N in the elongating cane. Additional applications of nitrogen are probably called for if these concentrations fall below the levels suggested, when the crop has another 10 or 12 months to go before harvest.

Studies of the "primary index" or the per cent total sugars in the active leaf sheaths showed a wide range in variability from replicated plots. The averages found at 11 months were not significantly different from canes which had received different amounts of nitrogen. Positive relationships were indicated between the per cent total sugars in the leaf sheaths, the per cent moisture in the same sheaths, the per cent total nitrogen in the leaf punches, and the yields of total dry weight; each of these items being increased as a result of increased nitrogen applications.

Both the total green and dry weights, and also the yields of millable cane, were increased when nitrogen was increased. The greatest increase which occurred between 3 and 6 months suggests a dominant effect of age over season. Many interesting interactions between amounts and time of applying nitrogen are shown to have affected the cane yields.

The higher applications of nitrogen have resulted in poorer cane quality principally in the younger crops that were harvested. Interactions between amounts and time have also influenced cane quality.

Yields of sucrose, of total sugars, and of commercial sugars show their most

rapid increases between 6 and 12 months; the commercial sugar yield made at 12 months from the high nitrogen applications was outstanding. Both the total amount of nitrogen applied and its time of application have had an influence on commercial sugar yields, and these influences have in turn been different for crops harvested at different ages. Thus from a total application of 100 pounds of N for the crops harvested at 18 months or younger, best yields came when the total amount was on by 4 months, but when the crops were carried beyond 18 months, completion of the nitrogen fertilization at 6 months gave best results. On the other hand when 220 pounds were applied the best sugar yields after 12 months came when some of this total amount was held off until 11 months.

The total amounts of nitrogen recovered in the total dry weights reflected the differences in the amounts made available, but the recovery was less complete from the higher applications. The rate of uptake was fastest during the first 6 months.

Many interesting ratios are pointed out, more especially those found as nitrogen effects in the early growth stages before the nitrogen applications were completely assimilated. Thus the increased nitrogen applications have (1) reduced the ratio of per cent total sugars to per cent nitrogen; (2) lowered the ratio of N recovered to N applied; (3) increased the amount of nitrogen recovered per ton of cane harvested; (4) resulted in a lowered nitrogen efficiency, *i.e.,* higher amounts of N needed per ton of cane and sugar; (5) increased the ratio of per cent reducing sugars to per cent sucrose, especially during the first 18 months; (6) had little if any effect on the ratio of yields of total sugars to total dry weights, but have increased the ratio of tons of reducing sugars to tons of dry weight during the first 18 months; (7) had no effect on the ratio of tons sucrose to tons dry weight after 9 or 10 months, nor very little effect on that for commercial sugar to sucrose; and (8) not changed the ratio of millable cane yields to total green weights.

Weather relationships again show such differences in their efficiency during different stages of growth that significant interactions are suspected to exist between the weather elements and the age of the crop at the time these elements are being received.

ACKNOWLEDGMENT

The foregoing is a summary of many data collected from a special nitrogen study that was undertaken as a cooperative project under the guidance of the Director. Many members of the staff of the Chemistry department, of the Biochemical and of the Enzyme laboratories, and of the Agricultural department have participated in the harvesting of the crops, the taking and preparation of the many crop samples, the making of the numerous chemical analyses, and in the statistical studies that were all necessary before the results could be made ready for presentation. To all these and to others who have assisted us in various ways from time to time, we are sincerely indebted; this report would have been impossible without their individual contributions.

Appendix

Containing Summaries of Data and Statistical Measurements Thereof from Makiki Experiment 20-ATN

Avg.=General average — S.D.=Standard deviation
C.V.=Coefficient of variation — ns=Treatment effect not significant
M.d.r.*=Minimum difference required for significance (for odds of 19 to 1)

At the first harvest, a minimum difference between the average of the 5 "X" plots and the average of the 45 plots which had received 40 pounds of nitrogen, would be .94 x S.D.

At the second harvest, at 6 months, one may calculate the M.d.r.'s as follows:

For comparing the averages of X and C1: M.d.r.=1.27×S.D.
For comparing X or C1 with either B1 or A2: M.d.r.=1.11×S.D.
For comparing X or C1 with A1: M.d.r.=1.01×S.D.
For comparing B1 or A2 with A1: M.d.r.=.79×S.D.

At the third, fourth, and fifth harvests, these M.d.r.'s would be:

For comparing any two of the averages from Treatments X, B1, C1, A2, C2, or A3: M.d.r.=1.29×S.D.
For comparing averages from X, or B1, or C1, or A2, or C2, or A3 with either A1 or B2: M.d.r.=1.12×S.D.
For comparing A1 with B2: M.d.r.=.92×S.D.

At all later harvests the M.d.r. between the averages of any two treatments would be 1.28×S.D.

TABLE 1

PER CENT TOPS IN TOTAL GREEN WEIGHT

Treat-ments	No. of plots	Age and month of harvest: 3 mos. Aug.	6 mos. Nov.	9 mos. Feb.	10 mos. Mar.	11 mos. Apr.	12 mos. May	15 mos. Aug.	18 mos. Nov.	21 mos. Feb.	24 mos. May	27 mos. Aug.
X	5	100	41.70	28.38	23.21	22.58	24.03	16.11	14.03	12.20	12.20	15.42
A1	5	100	36.00	26.36	18.12	17.30	19.22	13.00	10.93	10.52	9.41	12.08
B1	5	See A1	34.50	23.80	17.41	17.79	19.87	12.73	12.95	11.33	10.60	11.88
C1	5	See A1	36.80	25.50	19.02	18.92	20.14	14.52	12.71	10.57	9.90	12.80
A2	5	See A1	34.90	27.79	21.31	20.83	21.01	15.19	12.08	11.03	11.12	12.40
B2	5	See A1	See A1	25.93	19.04	18.26	19.32	14.18	11.52	10.60	10.41	11.54
C2	5	See A1	See B1	25.36	19.08	18.33	20.87	14.60	13.25	11.63	11.08	13.76
A3	5	See A1	See A2	27.47	20.20	19.93	22.13	17.90	13.35	11.14	10.64	11.64
B3	5	See A1	See A1	See A1	See A1	See A1	21.58	16.40	12.45	11.05	10.99	11.74
C3	5	See A1	See A1	See B2	See B2	See B2	20.38	13.95	12.27	11.18	10.44	11.74
Avg.		100	36.13	26.32	19.68	19.24	20.85	14.86	12.55	11.13	10.68	12.50
S.D.		...	2.10	2.34	1.17	1.33	1.46	1.48	.92	1.09	1.32	1.69
C.V.		...	5.8	8.9	5.9	6.9	7.0	10.0	7.3	9.8	12.4	13.5
M.d.r.		...	*	*	*	*	1.87	1.91	1.18	ns	ns	2.16

*See note immediately following "Appendix."

**Note:* The M.d.r. between any two specific treatments at the first 5 harvests has been calculated from the formula $t \times S.D. \times \sqrt{\frac{1}{n1} + \frac{1}{n2}}$

TABLE 2

PER CENT MOISTURE IN TOTAL GREEN WEIGHT

Treat-ments	No. of plots	Age and month of harvest										
		3 mos. Aug.	6 mos. Nov.	9 mos. Feb.	10 mos. Mar.	11 mos. Apr.	12 mos. May	15 mos. Aug.	18 mos. Nov.	21 mos. Feb.	24 mos. May	27 mos. Aug.
X	5	79.32	76.86	75.39	72.68	71.04	69.86	71.87	71.59	69.79	69.81	70.73
A1	5	81.02	79.85	75.95	74.14	72.04	71.32	70.59	70.75	70.00	69.01	70.43
B1	5	See A1	80.77	76.65	75.95	72.41	71.95	71.62	72.56	69.66	69.00	70.59
C1	5	See A1	81.20	77.74	75.65	72.59	71.98	72.20	71.71	69.70	68.97	70.15
A2	5	See A1	77.92	76.64	74.46	71.59	72.37	71.46	70.85	68.96	68.87	69.83
B2	5	See A1	See A1	77.50	75.45	72.55	71.32	71.56	71.33	68.99	69.71	70.34
C2	5	See A1	See B1	77.83	76.80	72.54	72.42	72.64	72.13	70.44	69.94	70.85
A3	5	See A1	See A2	74.95	72.92	70.42	71.21	72.19	70.53	68.77	69.04	70.67
B3	5	See A1	See A1	See A1	See A1	See A1	71.07	72.64	72.37	69.72	69.26	70.56
C3	5	See A1	See A1	See B2	See B2	See B2	73.55	72.81	71.81	70.28	69.62	70.45
Avg.		80.85	79.49	76.58	74.76	71.90	71.70	71.96	71.56	69.63	69.32	70.48
S.D.		.86	.92	1.43	1.38	1.10	1.13	1.17	1.15	.69	.84	1.24
C.V.		1.1	1.2	1.9	1.8	1.5	1.6	1.6	1.6	1.0	1.2	1.8
M.d.r.		.80	*	*	*	*	1.44	ns	ns	.89	ns	ns

TABLE 3

PER CENT MOISTURE IN LEAF SHEATHS

Treatments	Age and month of harvest										
	3 mos. Aug.	6 mos. Nov.	9 mos. Feb.	10 mos. Mar.	11 mos. Apr.	12 mos. May	15 mos. Aug.	18 mos. Nov.	21 mos. Feb.	24 mos. May	27 mos. Aug.
X	81.40	81.94	79.33	77.36	75.31	74.90	74.19	73.41	73.67	72.39	71.12
A1	82.44	83.69	80.44	79.74	77.42	75.67	74.58	74.51	74.42	71.94	70.16
B1	See A1	84.94	82.40	79.58	78.29	76.48	75.45	74.99	73.48	72.57	69.36
C1	See A1	84.96	81.91	80.40	77.43	76.08	76.64	75.54	73.91	71.64	70.49
A2	See A1	81.30	80.88	79.54	77.66	76.61	75.44	74.92	73.44	71.47	70.40
B2	See A1	See A1	82.35	80.97	77.88	75.97	75.84	74.16	73.86	71.72	69.94
C2	See A1	See B1	81.84	81.16	77.46	76.52	77.57	75.41	74.48	72.34	69.93
A3	See A1	See A2	78.65	77.64	75.75	76.66	75.12	74.38	73.42	72.25	70.78
B3	See A1	See A1	See A1	See A1	See A1	76.62	76.88	75.78	73.92	72.02	69.73
C3	See A1	See A1	See B2	See B2	See B2	77.62	76.73	75.92	75.13	71.77	69.38
Avg.	82.34	83.42	80.98	79.55	77.15	76.31	75.84	74.90	73.97	72.01	70.13
S.D.	.85	.87	1.15	1.23	1.41	1.22	1.35	1.06	1.10	1.20	1.34
C.V.	1.0	1.0	1.4	1.5	1.8	1.6	1.8	1.4	1.5	1.7	1.9
M.d.r.	.80	*	*	*	*	ns	1.75	1.36	ns	ns	ns

TABLE 4

PER CENT MOISTURE IN LEAF BLADES

	Age and month of harvest										
Treatments	3 mos. Aug.	6 mos. Nov.	9 mos. Feb.	10 mos. Mar.	11 mos. Apr.	12 mos. May	15 mos. Aug.	18 mos. Nov.	21 mos. Feb.	24 mos. May	27 mos. Aug.
X	71.93	71.62	69.50	68.21	67.12	66.96	63.76	60.66	63.00	60.52	58.21
A1	73.42	72.93	70.14	69.34	67.04	67.44	63.04	62.71	65.83	60.69	57.97
B1	See A1	73.71	71.24	69.75	67.83	68.64	65.04	64.95	63.68	61.62	58.03
C1	See A1	74.37	72.25	70.25	67.08	67.91	64.92	63.72	64.78	61.10	58.96
A2	See A1	70.85	71.05	69.52	67.28	68.17	63.90	63.67	63.06	60.72	58.90
B2	See A1	See A1	71.40	70.42	67.20	67.41	64.34	63.07	63.78	60.20	57.73
C2	See A1	See B1	71.47	70.90	67.80	68.35	65.75	64.28	64.82	62.28	59.28
A3	See A1	See A2	69.28	68.74	65.24	68.03	63.07	62.19	63.55	61.14	57.69
B3	See A1	See A1	See A1	See A1	See A1	68.14	64.62	63.90	63.33	61.25	58.57
C3	See A1	See A1	See B2	See B2	See B2	68.68	64.62	64.47	64.27	61.67	58.78
Avg.	73.27	72.68	70.79	69.64	67.08	67.97	64.31	63.36	64.01	61.12	58.41
S.D.	.89	1.22	1.07	1.20	1.80	1.24	1.67	.98	1.51	1.32	1.57
C.V.	1.2	1.7	1.5	1.7	2.7	1.8	2.6	1.5	2.4	2.2	2.7
M.d.r.	.84	*	*	*	*	ns	ns	1.32	ns	ns	ns

TABLE 5

PER CENT REDUCING SUGARS IN TOTAL DRY WEIGHT

	Age and month of harvest										
Treatments	3 mos. Aug.	6 mos. Nov.	9 mos. Feb.	10 mos. Mar.	11 mos. Apr.	12 mos. May	15 mos. Aug.	18 mos. Nov.	21 mos. Feb.	24 mos. May	27 mos. Aug.
X	2.842	2.783	2.091	1.276	1.049	1.172	1.744	1.459	.857	1.070	1.831
A1	3.782	4.566	2.558	2.015	1.185	1.416	1.485	1.498	.880	.982	1.636
B1	See A1	5.224	3.134	2.817	1.551	1.507	1.748	2.001	.976	.833	1.616
C1	See A1	4.978	3.546	2.759	1.746	1.707	1.908	1.934	.855	.932	1.508
A2	See A1	3.724	2.840	1.932	1.228	1.484	1.691	1.590	.852	.970	1.320
B2	See A1	See A1	3.552	2.740	1.460	1.471	1.726	1.565	.884	1.074	1.491
C2	See A1	See B1	3.889	3.576	1.566	1.782	1.957	1.810	.915	1.003	1.564
A3	See A1	See A2	2.081	1.303	.886	1.119	2.111	1.480	.754	.980	1.425
B3	See A1	See A1	See A1	See A1	See A1	1.187	2.193	1.874	.815	.932	1.421
C3	See A1	See A1	See B2	See B2	See B2	1.835	2.137	1.731	1.044	1.036	1.724
Avg.	3.688	4.393	2.961	2.302	1.334	1.468	1.870	1.694	.883	.981	1.554
S.D.	.579	.497	.783	.688	.351	.279	.340	.365	.128	.178	.370
C.V.	15.7	11.3	26.4	30.0	26.3	19.0	18.2	21.5	14.5	18.1	23.8
M.d.r.	.544	*	*	*	*	.357	.433	ns	ns	ns	ns

TABLE 6

PER CENT REDUCING SUGARS IN ELONGATING CANE

	Age and month of harvest										
Treatments	3 mos. Aug.	6 mos. Nov.	9 mos. Feb.	10 mos. Mar.	11 mos. Apr.	12 mos. May	15 mos. Aug.	18 mos. Nov.	21 mos. Feb.	24 mos. May	27 mos. Aug.
X	1.01	1.04	.83	.51	.99	1.12	1.16	1.26	1.02	.90	1.29
A1	1.22	1.08	.93	.66	1.04	1.54	1.62	1.44	1.24	1.02	1.33
B1	See A1	1.08	.90	.57	1.14	1.34	1.71	1.58	1.08	1.02	1.10
C1	See A1	1.00	.85	.51	1.05	1.52	1.75	1.70	1.47	1.10	1.23
A2	See A1	1.13	.80	.45	.95	1.22	1.65	1.77	1.29	.99	1.45
B2	See A1	See A1	.81	.70	1.06	1.31	1.61	1.60	1.17	.86	1.30
C2	See A1	See B1	.87	.86	1.19	1.36	1.78	1.67	1.24	.92	1.32
A3	See A1	See A2	.84	.49	.91	1.08	1.40	1.49	1.18	.85	1.27
B3	See A1	See A1	See A1	See A1	See A1	1.09	1.61	1.51	1.27	.87	1.17
C3	See A1	See A1	See B2	See B2	See B2	1.43	1.78	1.81	1.46	1.00	1.62
Avg.	1.20	1.08	.85	.59	1.04	1.30	1.61	1.58	1.24	.95	1.31
S.D.	.22	.14	.15	.20	.17	.20	.22	.25	.20	.19	.28
C.V.	18.3	18.5	17.6	33.9	16.3	15.4	13.7	15.8	16.1	20.0	21.4
M.d.r.	.21	*	*	*	*	.26	.28	.32	.26	ns	ns

TABLE 7

PER CENT SUCROSE IN TOTAL DRY WEIGHT

	Age and month of harvest										
Treatments	3 mos. Aug.	6 mos. Nov.	9 mos. Feb.	10 mos. Mar.	11 mos. Apr.	12 mos. May	15 mos. Aug.	18 mos. Nov.	21 mos. Feb.	24 mos. May	27 mos. Aug.
X	5.598	9.295	31.357	36.788	36.918	37.267	40.801	39.322	42.648	43.152	38.063
A1	5.308	11.685	32.199	37.009	39.872	39.583	41.816	41.034	43.635	44.856	40.631
B1	See A1	11.078	29.979	35.615	38.845	39.708	40.447	40.563	43.901	44.897	40.681
C1	See A1	9.153	29.616	34.456	38.291	38.445	42.155	41.479	44.045	45.326	41.342
A2	See A1	14.620	30.704	35.496	37.034	37.826	39.742	41.951	44.517	44.716	41.209
B2	See A1	See A1	28.449	35.255	38.584	39.011	41.192	41.517	43.814	45.498	41.204
C2	See A1	See B1	28.927	34.170	38.715	38.025	41.435	41.284	44.057	45.133	40.857
A3	See A1	See A2	34.165	38.167	40.401	38.132	38.484	40.594	43.534	44.226	41.088
B3	See A1	See A1	See A1	See A1	See A1	37.948	39.509	41.287	44.359	45.608	41.630
C3	See A1	See A1	See B2	See B2	See B2	38.367	40.716	42.098	43.751	45.139	41.609
Avg.	5.337	11.659	30.675	35.869	38.582	38.431	40.630	41.113	43.826	44.855	40.832
S.D.	.561	1.701	1.754	1.361	1.496	1.708	2.229	1.530	1.281	1.208	1.568
C.V.	10.5	14.6	5.7	3.8	3.9	4.4	5.5	3.7	2.9	2.7	3.8
M.d.r.	ns	*	*	*	*	ns	ns	ns	ns	ns	2.010

TABLE 8

PER CENT SUCROSE IN ELONGATING CANE

Treatments	Age and month of harvest										
	3 mos. Aug.	6 mos. Nov.	9 mos. Feb.	10 mos. Mar.	11 mos. Apr.	12 mos. May	15 mos. Aug.	18 mos. Nov.	21 mos. Feb.	24 mos. May	27 mos. Aug.
X	.90	.24	1.19	1.88	1.27	1.34	1.45	1.36	2.73	2.43	2.55
A1	.56	.26	1.12	1.72	1.58	1.08	1.16	1.29	2.53	2.24	2.13
B1	See A1	.24	.81	1.91	1.39	1.16	1.00	1.05	3.35	1.97	2.92
C1	See A1	.26	.96	1.71	1.53	1.37	.91	.96	2.53	2.45	2.48
A2	See A1	.39	1.16	1.69	1.53	1.29	1.25	.94	3.14	2.51	2.84
B2	See A1	See A1	1.01	1.48	1.45	1.45	.89	1.09	2.99	2.22	2.52
C2	See A1	See B1	1.02	1.44	1.46	1.20	.75	1.04	2.85	2.07	2.67
A3	See A1	See A2	1.21	2.01	1.69	1.12	1.23	.99	3.45	2.38	2.27
B3	See A1	See A1	See A1	See A1	See A1	1.22	1.02	.85	2.25	2.30	3.07
C3	See A1	See A1	See B2	See B2	See B2	1.11	.96	.82	2.32	2.25	2.13
Avg.	.60	.28	1.06	1.73	1.49	1.23	1.06	1.04	2.81	2.28	2.56
S.D.	.31	.12	.23	.30	.29	.36	.29	.29	.87	.48	.53
C.V.	51.7	42.9	21.7	17.3	19.5	29.3	27.4	27.9	31.0	21.1	20.7
M.d.r.	.29	*	*	*	*	ns	.37	ns	ns	ns	ns

TABLE 9

PER CENT TOTAL SUGARS IN TOTAL DRY WEIGHT

Treatments	Age and month of harvest										
	3 mos. Aug.	6 mos. Nov.	9 mos. Feb.	10 mos. Mar.	11 mos. Apr.	12 mos. May	15 mos. Aug.	18 mos. Nov.	21 mos. Feb.	24 mos. May	27 mos. Aug.
X	8.723	12.567	35.099	40.000	39.911	40.400	44.672	42.849	45.751	46.493	41.969
A1	9.373	16.878	36.451	40.972	42.623	43.083	45.504	44.691	46.802	48.187	44.408
B1	See A1	16.887	34.690	40.311	42.441	43.305	44.323	44.699	47.188	48.093	44.439
C1	See A1	14.613	34.720	39.029	42.053	42.175	46.292	45.596	47.218	48.645	45.026
A2	See A1	19.115	35.161	39.296	40.241	41.307	43.523	45.749	47.712	48.040	44.699
B2	See A1	See A1	33.499	39.852	42.140	42.536	45.086	45.267	47.004	48.966	44.864
C2	See A1	See B1	34.349	39.544	42.318	41.807	45.573	45.268	47.282	48.511	44.572
A3	See A1	See A2	38.043	41.318	43.392	41.258	42.638	44.211	46.580	47.534	44.676
B3	See A1	See A1	See A1	See A1	See A1	41.153	43.782	45.324	47.510	48.771	45.234
C3	See A1	See A1	See B2	See B2	See B2	42.221	44.996	46.040	47.200	48.551	45.523
Avg.	9.308	16.669	35.252	40.040	41.890	41.924	44.639	44.970	47.025	48.179	44.541
S.D.	.921	1.933	1.651	1.434	1.629	1.733	2.210	1.449	1.370	1.233	1.480
C.V.	9.9	11.6	4.7	3.6	3.8	4.2	5.0	3.2	2.9	2.6	3.3
M.d.r.	ns	*	*	*	*	ns	ns	ns	ns	ns	1.900

TABLE 10

PER CENT TOTAL SUGARS IN ELONGATING CANE

	Age and month of harvest										
Treatments	3 mos. Aug.	6 mos. Nov.	9 mos. Feb.	10 mos. Mar.	11 mos. Apr.	12 mos. May	15 mos. Aug.	18 mos. Nov.	21 mos. Feb.	24 mos. May	27 mos. Aug.
X	1.71	1.29	2.02	2.39	2.26	2.46	2.61	2.61	3.75	3.33	3.84
A1	1.70	1.35	2.05	2.39	2.61	2.80	2.78	2.72	3.77	3.26	3.45
B1	See A1	1.31	1.70	2.48	2.54	2.49	2.71	2.64	4.43	2.99	4.02
C1	See A1	1.26	1.81	2.22	2.58	2.88	2.66	2.66	4.00	3.55	3.71
A2	See A1	1.52	1.95	2.14	2.48	2.51	2.90	2.50	4.43	3.50	4.29
B2	See A1	See A1	1.82	2.16	2.52	2.76	2.51	2.69	4.16	3.08	3.82
C2	See A1	See B1	1.89	2.30	2.65	2.57	2.53	2.71	4.09	2.99	3.99
A3	See A1	See A2	2.05	2.49	2.60	2.20	2.64	2.48	4.63	3.23	3.55
B3	See A1	See A1	See A1	See A1	See A1	2.32	2.63	2.36	3.52	3.17	4.23
C3	See A1	See A1	See B2	See B2	See B2	2.54	2.74	2.63	3.78	3.25	3.74
Avg.	1.71	1.36	1.91	2.32	2.53	2.55	2.67	2.60	4.05	3.23	3.86
S.D.	.26	.16	.23	.32	.27	.31	.27	.33	.81	.48	.59
C.V.	15.2	11.8	12.0	13.8	10.7	12.2	10.1	12.7	20.0	14.9	15.3
M.d.r.	ns	*	*	*	*	.40	ns	ns	ns	ns	ns

TABLE 11

PER CENT TOTAL SUGARS IN LEAF SHEATHS

	Age and month of harvest										
Treatments	3 mos. Aug.	6 mos. Nov.	9 mos. Feb.	10 mos. Mar.	11 mos. Apr.	12 mos. May	15 mos. Aug.	18 mos. Nov.	21 mos. Feb.	24 mos. May	27 mos. Aug.
X	12.677	6.626	9.578	10.399	11.563	10.222	10.492	9.595	11.035	12.945	13.358
A1	12.662	7.360	9.699	10.428	12.740	11.906	10.984	8.779	11.210	12.540	13.774
B1	See A1	8.461	8.611	11.868	12.776	12.016	10.733	8.795	12.421	13.105	15.036
C1	See A1	8.105	9.268	11.941	13.642	11.997	11.007	8.361	12.029	13.761	14.290
A2	See A1	6.781	8.794	10.359	11.543	9.799	10.496	9.183	11.798	13.930	13.781
B2	See A1	See A1	9.460	11.218	12.502	12.546	11.026	8.970	12.486	14.218	13.365
C2	See A1	See B1	9.652	11.776	13.180	11.464	10.591	8.597	11.225	14.375	15.370
A3	See A1	See A2	9.592	10.394	12.098	9.375	10.630	9.019	11.258	13.314	12.672
B3	See A1	See A1	See A1	See A1	See A1	11.022	10.692	8.621	11.578	13.774	13.812
C3	See A1	See A1	See B2	See B2	See B2	11.827	11.111	8.804	10.667	14.549	14.944
Avg.	12.664	7.466	9.332	11.048	12.506	11.217	10.776	8.872	11.571	13.651	14.040
S.D.	1.094	.400	.762	1.131	1.133	1.349	1.063	.849	1.480	1.386	1.960
C.V.	8.6	5.4	8.2	10.2	9.1	12.0	9.9	9.6	12.8	10.2	14.0
M.d.r.	ns	*	*	*	*	1.732	ns	ns	ns	ns	ns

TABLE 12

PER CENT NITROGEN IN TOTAL DRY WEIGHT

	Age and month of harvest										
Treatments	3 mos. Aug.	6 mos. Nov.	9 mos. Feb.	10 mos. Mar.	11 mos. Apr.	12 mos. May	15 mos. Aug.	18 mos. Nov.	21 mos. Feb.	24 mos. May	27 mos. Aug.
X	.836	.632	.349	.245	.227	.172	.144	.142	.130	.129	.137
A1	.996	.710	.376	.305	.258	.219	.154	.144	.148	.124	.130
B1	See A1	.840	.513	.425	.345	.268	.197	.184	.156	.132	.127
C1	See A1	.950	.553	.462	.367	.278	.205	.178	.142	.140	.138
A2	See A1	.519	.402	.302	.262	.235	.177	.153	.126	.126	.126
B2	See A1	See A1	.498	.368	.316	.256	.192	.171	.144	.138	.134
C2	See A1	See B1	.586	.460	.364	.298	.237	.195	.172	.143	.146
A3	See A1	See A2	.298	.237	.200	.242	.189	.152	.127	.121	.126
B3	See A1	See A1	See A1	See A1	See A1	.243	.223	.176	.146	.124	.128
C3	See A1	See A1	See B2	See B2	See B2	.333	.241	.189	.168	.146	.139
Avg.	.980	.710	.447	.351	.292	.255	.196	.168	.146	.132	.133
S.D.	.060	.053	.064	.045	.031	.032	.022	.016	.012	.010	.016
C.V.	6.1	6.7	14.3	12.8	10.6	12.5	11.2	9.5	8.2	7.6	12.0
M.d.r.	.056	*	*	*	*	.041	.028	.020	.015	.013	ns

TABLE 13

PER CENT NITROGEN IN LEAF-PUNCH SAMPLES FROM BLADES

	Age and month of harvest										
Treatments	3 mos. Aug.	6 mos. Nov.	9 mos. Feb.	10 mos. Mar.	11 mos. Apr.	12 mos. May	15 mos. Aug.	18 mos. Nov.	21 mos. Feb.	24 mos. May	27 mos. Aug.
X	1.61	1.37	1.24	1.12	1.03	1.01	.89	.88	.93	.91	.81
A1	1.86	1.64	1.36	1.35	1.28	1.14	.91	.91	.96	.92	.81
B1	See A1	1.76	1.49	1.46	1.38	1.18	1.02	1.00	.96	.90	.74
C1	See A1	1.87	1.50	1.51	1.42	1.26	1.07	1.03	.99	.92	.76
A2	See A1	1.38	1.39	1.36	1.32	1.15	.94	.97	.95	.93	.79
B2	See A1	See A1	1.49	1.47	1.36	1.21	.99	.99	.95	.91	.78
C2	See A1	See B1	1.52	1.52	1.43	1.24	1.09	1.09	1.06	.91	.77
A3	See A1	See A2	1.17	1.16	1.07	1.27	1.00	.93	.92	.91	.80
B3	See A1	See A1	See A1	See A1	See A1	1.29	1.05	1.01	.99	.90	.77
C3	See A1	See A1	See B2	See B2	See B2	1.37	1.15	1.07	1.06	.95	.76
Avg.	1.83	1.61	1.40	1.37	1.29	1.21	1.01	.99	.98	.92	.78
S.D.	.04	.05	.06	.05	.06	.07	.06	.06	.04	.05	.06
C.V.	2.2	3.1	4.3	3.6	4.7	5.8	5.9	6.1	4.1	5.4	7.7
M.d.r.	.04	*	*	*	*	.09	.08	.08	.06	ns	ns

TABLE 14

PER CENT NITROGEN IN LEAF BLADES (ENTIRE)

	Age and month of harvest										
Treatments	3 mos. Aug.	6 mos. Nov.	9 mos. Feb.	10 mos. Mar.	11 mos. Apr.	12 mos. May	15 mos. Aug.	18 mos. Nov.	21 mos. Feb.	24 mos. May	27 mos. Aug.
X	1.09	1.10	1.02	.86	.79	.75	.68	.77	.74	.71	.62
A1	1.30	1.26	1.08	1.04	.94	.87	.69	.78	.74	.68	.61
B1	See A1	1.38	1.24	1.08	1.06	.91	.79	.84	.71	.66	.54
C1	See A1	1.44	1.23	1.13	1.03	.92	.83	.86	.75	.66	.56
A2	See A1	1.05	1.15	1.02	.98	.88	.72	.84	.71	.68	.56
B2	See A1	See A1	1.23	1.14	1.02	.91	.74	.81	.71	.66	.59
C2	See A1	See B1	1.28	1.20	1.06	.91	.88	.92	.79	.66	.57
A3	See A1	See A2	.96	.87	.82	.95	.75	.78	.72	.66	.62
B3	See A1	See A1	See A1	See A1	See A1	.95	.82	.85	.74	.65	.57
C3	See A1	See A1	See B2	See B2	See B2	1.04	.88	.89	.81	.68	.54
Avg.	1.28	1.24	1.15	1.04	.96	.91	.78	.83	.74	.67	.58
S.D.	.05	.05	.08	.11	.06	.06	.05	.06	.05	.04	.06
C.V.	3.9	4.0	7.0	7.7	6.2	6.6	6.4	7.2	6.8	6.0	10.3
M.d.r.	.05	*	*	*	*	.08	.07	.08	.06	ns	ns

TABLE 15

PER CENT NITROGEN IN CRUSHER JUICES

	Age and month of harvest										
Treatments	3 mos. Aug.	6 mos. Nov.	9 mos. Feb.	10 mos. Mar.	11 mos. Apr.	12 mos. May	15 mos. Aug.	18 mos. Nov.	21 mos. Feb.	24 mos. May	27 mos. Aug.
X	....	.012	.008	.009	.010	.009	.006	.005	.005	.006	.005
A1	....	.016	.013	.015	.016	.015	.008	.006	.006	.007	.006
B1	....	.032	.024	.030	.032	.023	.018	.010	.009	.007	.006
C1	....	.045	.025	.035	.035	.023	.017	.011	.010	.008	.007
A2	....	.010	.012	.014	.015	.017	.012	.007	.007	.006	.004
B2	....	See A1	.021	.022	.028	.019	.014	.009	.009	.008	.006
C2	....	See B1	.027	.031	.031	.024	.024	.012	.011	.010	.007
A3	....	See A2	.008	.009	.010	.014	.010	.007	.006	.005	.005
B3	....	See A1	See A1	See A1	See A1	.018	.014	.011	.009	.007	.006
C3	....	See A1	See B2	See B2	See B2	.028	.018	.010	.010	.008	.007
Avg.	....	.021	.017	.021	.022	.019	.014	.009	.008	.007	.006
S.D.	....	.004	.006	.005	.004	.005	.003	.002	.001	.001	.001
C.V.	....	19.0	35.3	23.8	18.2	26.3	21.4	22.2	12.5	20.0	16.7
M.d.r.	....	*	*	*	*	.006	.004	.003	.002	.001	.001

TABLE 16

P.P.M. AMINO NITROGEN IN ELONGATING CANE

Treatments	Age and month of harvest: 3 mos. Aug.	6 mos. Nov.	9 mos. Feb.	10 mos. Mar.	11 mos. Apr.	12 mos. May	15 mos. Aug.	18 mos. Nov.	21 mos. Feb.	24 mos. May	27 mos. Aug.
X	132	142	156	135	138	136	124	135	124	137	126
A1	164	189	214	219	182	185	145	164	147	168	165
B1	See A1	192	275	255	221	203	161	175	174	170	176
C1	See A1	210	216	287	224	199	177	154	146	173	152
A2	See A1	158	225	188	186	165	140	166	152	170	142
B2	See A1	See A1	242	242	196	195	162	168	145	193	176
C2	See A1	See B1	258	245	221	185	180	176	161	186	186
A3	See A1	See A2	197	159	165	188	150	150	120	168	142
B3	See A1	See A1	See A1	See A1	See A1	231	198	182	139	176	151
C3	See A1	See A1	See B2	See B2	See B2	224	179	165	140	187	190
Avg.	161	181	223	216	192	191	162	164	145	173	161
S.D.	38	38	31	42	19	29	18	18	28	23	38
C.V.	23.7	21.0	13.9	19.0	9.9	15.2	11.1	11.0	19.3	13.3	23.6
M.d.r.	ns	*	*	*	*	37	22	24	ns	30	ns

TABLE 17

TOTAL GREEN WEIGHT—TONS PER ACRE

Treatments	Age and month of harvest: 3 mos. Aug.	6 mos. Nov.	9 mos. Feb.	10 mos. Mar.	11 mos. Apr.	12 mos. May	15 mos. Aug.	18 mos. Nov.	21 mos. Feb.	24 mos. May	27 mos. Aug.
X	7.8	38.1	45.3	45.5	49.8	55.1	60.0	64.2	59.5	58.7	59.9
A1	10.8	62.1	94.4	82.8	82.5	93.4	106.6	132.6	93.1	97.9	82.3
B1	See A1	72.2	97.4	97.2	105.4	105.9	121.3	128.7	116.3	119.3	93.8
C1	See A1	68.7	105.5	90.8	96.2	110.9	123.2	119.9	137.6	112.8	96.9
A2	See A1	48.8	75.5	73.7	71.8	82.9	98.7	107.6	122.1	96.0	99.4
B2	See A1	See A1	102.4	90.5	94.0	107.9	116.3	146.3	140.4	97.2	86.7
C2	See A1	See B1	104.1	96.5	109.9	111.2	118.3	142.2	128.5	128.5	92.8
A3	See A1	See A2	61.6	56.7	55.6	69.1	87.3	105.1	96.8	88.1	89.7
B3	See A1	See A1	See A1	See A1	See A1	96.7	120.0	146.0	125.4	115.0	100.6
C3	See A1	See A1	See B2	See B2	See B2	101.0	141.3	163.1	149.1	129.1	108.9
Avg.	10.5	59.7	85.8	79.2	83.2	93.4	109.3	125.5	116.9	104.3	91.1
S.D.	1.9	6.5	7.9	8.4	9.1	9.3	13.6	16.8	15.8	16.2	16.4
C.V.	18.8	10.9	9.1	10.6	11.0	10.0	12.4	13.4	13.6	15.6	17.9
M.d.r.	1.9	*	*	*	*	12.0	17.4	21.5	20.3	20.8	20.9

TABLE 18

TOTAL DRY WEIGHT—TONS PER ACRE

Treatments	3 mos. Aug.	6 mos. Nov.	9 mos. Feb.	10 mos. Mar.	11 mos. Apr.	12 mos. May	15 mos. Aug.	18 mos. Nov.	21 mos. Feb.	24 mos. May	27 mos. Aug.
	Age and month of harvest										
X	1.58	8.77	11.16	12.43	14.37	16.55	16.87	18.26	17.98	17.78	17.44
A1	2.05	12.48	22.72	21.43	23.02	26.65	31.32	38.60	27.94	30.32	24.50
B1	See A1	13.91	22.86	23.47	29.11	29.70	34.62	35.42	35.26	37.05	27.67
C1	See A1	12.93	23.53	22.14	26.34	31.00	34.20	33.90	41.62	35.00	29.14
A2	See A1	10.78	17.61	18.84	20.47	22.91	28.18	31.34	37.85	29.83	30.02
B2	See A1	See A1	23.08	22.24	25.76	30.92	32.99	41.93	43.42	29.40	25.75
C2	See A1	See B1	23.06	22.48	30.16	30.68	32.33	39.66	38.07	38.48	27.24
A3	See A1	See A2	15.43	15.30	16.39	19.81	24.28	31.01	30.16	27.36	26.37
B3	See A1	See A1	See A1	See A1	See A1	27.96	32.77	40.34	38.00	35.33	29.64
C3	See A1	See A1	See B2	See B2	See B2	26.68	38.43	46.02	44.40	39.20	32.28
Avg.	2.00	12.10	19.93	19.79	23.31	26.29	30.60	35.65	35.47	31.98	27.00
S.D.	.33	1.39	2.33	2.71	2.74	2.44	3.97	3.20	4.64	4.92	5.49
C.V.	16.5	11.5	11.7	13.7	11.8	9.3	13.0	9.0	13.1	15.4	20.3
M.d.r.	.31	*	*	*	*	3.13	5.10	4.11	5.95	6.31	7.02

TABLE 19

TONS MILLABLE CANE PER ACRE (T.C.A.)

Treatments	3 mos. Aug.	6 mos. Nov.	9 mos. Feb.	10 mos. Mar.	11 mos. Apr.	12 mos. May	15 mos. Aug.	18 mos. Nov.	21 mos. Feb.	24 mos. May	27 mos. Aug.
	Age and month of harvest										
X	....	22.2	32.5	34.9	38.7	42.0	50.2	55.2	52.1	51.6	50.6
A1	....	39.8	69.1	67.8	68.2	75.4	92.7	117.5	83.3	88.5	72.7
B1	....	47.2	74.1	80.4	86.6	84.9	105.7	112.0	103.1	106.5	82.8
C1	....	43.4	78.6	73.5	78.0	88.4	105.5	104.6	123.2	101.7	84.9
A2	....	31.8	54.6	58.0	56.8	65.5	83.7	94.6	108.6	85.3	87.2
B2	....	See A1	75.8	73.3	76.8	87.1	99.9	129.3	125.6	87.3	76.8
C2	....	See B1	77.7	78.0	89.6	88.0	100.9	123.1	113.8	114.2	80.3
A3	....	See A2	44.7	45.2	44.4	53.8	71.6	91.1	86.0	78.8	79.1
B3	....	See A1	See A1	See A1	See A1	76.0	100.3	127.9	111.7	102.4	88.9
C3	....	See A1	See B2	See B2	See B2	80.3	121.8	143.1	132.4	115.6	96.3
Avg.	....	38.3	63.4	63.9	67.4	74.1	93.2	109.8	104.0	93.2	79.9
S.D.	....	4.55	5.38	6.71	6.88	7.60	11.47	14.25	14.48	14.56	15.15
C.V.	....	11.9	8.5	10.5	10.2	10.3	12.3	13.0	13.9	15.6	19.0
M.d.r.	....	*	*	*	*	9.8	14.7	18.3	18.6	18.7	19.4

TABLE 20

YIELD PER CENT CANE (Y%C)

Treatments	Age and month of harvest: 3 mos. Aug.	6 mos. Nov.	9 mos. Feb.	10 mos. Mar.	11 mos. Apr.	12 mos. May	15 mos. Aug.	18 mos. Nov.	21 mos. Feb.	24 mos. May	27 mos. Aug.
X	....	2.13	8.6	10.5	12.7	12.1	11.6	10.7	12.5	12.7	10.8
A1	....	1.14	8.3	9.1	11.8	11.8	11.4	10.7	12.4	12.9	11.4
B1	....	.63	7.0	8.6	11.0	11.4	11.0	10.5	12.6	13.2	11.4
C1	....	.32	6.8	8.1	11.0	11.2	11.4	11.0	12.8	13.2	12.3
A2	....	2.96	8.2	9.6	11.6	11.3	11.1	11.7	13.4	13.6	11.6
B2	....	See A1	6.8	8.9	11.1	11.5	11.4	11.0	12.8	12.8	11.4
C2	....	See B1	6.4	7.9	11.0	11.2	10.2	10.5	12.0	12.4	10.8
A3	....	See A2	9.9	10.9	12.8	11.9	10.5	11.4	13.4	13.2	11.2
B3	....	See A1	See A1	See A1	See A1	11.6	10.2	10.3	12.7	13.3	11.5
C3	....	See A1	See B2	See B2	See B2	10.5	10.8	10.7	12.8	13.5	11.2
Avg.	....	1.42	7.7	9.2	11.6	11.5	11.0	10.8	12.7	13.1	11.4
S.D.	....	.54	1.01	.62	.66	.69	.71	.48	.57	.52	.89
C.V.	....	38.0	13.1	6.7	5.7	6.0	6.5	4.4	4.5	4.0	7.8
M.d.r.	....	*	*	*	*	.9	.9	.6	.7	.7	ns

TABLE 21

TONS REDUCING SUGARS PER ACRE

Treatments	Age and month of harvest: 3 mos. Aug.	6 mos. Nov.	9 mos. Feb.	10 mos. Mar.	11 mos. Apr.	12 mos. May	15 mos. Aug.	18 mos. Nov.	21 mos. Feb.	24 mos. May	27 mos. Aug.
X	.049	.25	.23	.16	.15	.19	.29	.27	.15	.19	.32
A1	.078	.57	.58	.42	.27	.38	.46	.58	.24	.30	.39
B1	See A1	.72	.67	.64	.44	.45	.60	.68	.34	.31	.44
C1	See A1	.64	.82	.61	.46	.53	.65	.65	.36	.33	.42
A2	See A1	.40	.50	.36	.25	.34	.47	.50	.32	.29	.39
B2	See A1	See A1	.78	.58	.37	.45	.57	.66	.38	.32	.38
C2	See A1	See B1	.88	.77	.47	.54	.63	.72	.35	.40	.41
A3	See A1	See A2	.32	.20	.15	.22	.50	.46	.23	.27	.37
B3	See A1	See A1	See A1	See A1	See A1	.34	.72	.75	.31	.33	.42
C3	See A1	See A1	See B2	See B2	See B2	.48	.82	.79	.46	.40	.53
Avg.	.075	.54	.60	.47	.32	.39	.57	.61	.31	.31	.41
S.D.	.020	.08	.14	.11	.08	.07	.11	.13	.06	.08	.09
C.V.	26.7	14.8	23.3	23.4	25.0	17.9	19.3	21.3	19.4	25.8	22.0
M.d.r.	.018	*	*	*	*	.09	.14	.17	.08	.10	ns

TABLE 22

TONS SUCROSE PER ACRE

	Age and month of harvest										
Treatments	3 mos. Aug.	6 mos. Nov.	9 mos. Feb.	10 mos. Mar.	11 mos. Apr.	12 mos. May	15 mos. Aug.	18 mos. Nov.	21 mos. Feb.	24 mos. May	27 mos. Aug.
X	.089	.82	3.51	4.58	5.32	6.19	6.86	7.19	7.71	7.70	6.64
A1	.109	1.46	7.30	7.92	9.17	10.54	13.11	15.83	12.16	13.59	10.05
B1	See A1	1.57	6.91	8.39	11.33	11.79	14.00	14.41	15.53	16.60	11.31
C1	See A1	1.20	6.97	7.63	10.09	11.92	14.42	14.08	18.34	15.86	12.17
A2	See A1	1.58	5.41	6.68	7.58	8.67	11.19	13.16	16.81	13.33	12.39
B2	See A1	See A1	6.60	7.84	9.93	12.08	13.60	17.32	19.10	13.37	10.61
C2	See A1	See B1	6.64	7.71	11.70	11.69	13.34	16.31	16.80	17.34	11.24
A3	See A1	See A2	5.25	5.82	6.60	7.54	9.38	12.62	13.17	12.09	10.83
B3	See A1	See A1	See A1	See A1	See A1	10.64	12.91	16.65	16.87	16.13	12.39
C3	See A1	See A1	See B2	See B2	See B2	10.21	15.71	19.35	19.44	17.74	13.46
Avg.	.107	1.41	6.07	7.07	8.97	10.13	12.45	14.69	15.59	14.37	11.11
S.D.	.022	.30	.84	1.03	1.14	1.10	1.75	2.03	2.10	2.33	2.48
C.V.	20.6	21.3	13.8	14.6	12.7	10.9	14.1	13.8	13.5	16.2	22.3
M.d.r.	ns	*	*	*	*	1.41	2.25	2.60	2.70	2.98	3.17

TABLE 23

TONS TOTAL SUGARS PER ACRE

	Age and month of harvest										
Treatments	3 mos. Aug.	6 mos. Nov.	9 mos. Feb.	10 mos. Mar.	11 mos. Apr.	12 mos. May	15 mos. Aug.	18 mos. Nov.	21 mos. Feb.	24 mos. May	27 mos. Aug.
X	.142	1.12	3.93	4.98	5.75	6.71	7.51	7.83	8.27	8.30	7.33
A1	.193	2.11	8.26	8.76	9.80	11.48	14.26	17.24	13.04	14.60	10.97
B1	See A1	2.37	7.95	9.48	12.37	12.86	15.33	15.85	16.69	17.78	12.34
C1	See A1	1.90	8.16	8.63	11.09	13.07	15.83	15.47	19.67	17.02	13.23
A2	See A1	2.06	6.19	7.40	8.23	9.46	12.25	14.35	18.02	14.32	13.44
B2	See A1	See A1	7.74	8.83	10.84	13.16	14.89	18.89	20.49	14.40	11.55
C2	See A1	See B1	7.88	8.88	12.79	12.84	14.67	17.89	18.03	18.65	12.24
A3	See A1	See A2	5.85	6.30	7.08	8.16	10.38	13.75	14.09	12.99	11.78
B3	See A1	See A1	See A1	See A1	See A1	11.54	14.31	18.28	18.07	17.25	13.46
C3	See A1	See A1	See B2	See B2	See B2	11.23	17.36	21.16	20.95	19.08	14.70
Avg.	.188	2.03	6.99	7.91	9.75	11.05	13.68	16.07	16.73	15.44	12.10
S.D.	.041	.36	.85	1.06	1.21	1.17	1.87	2.17	2.25	2.50	2.63
C.V.	21.8	17.7	12.2	13.4	12.4	10.6	13.7	13.5	13.4	16.2	21.7
M.d.r.	.039	*	*	*	*	1.50	2.40	2.78	2.88	3.21	3.37

TABLE 24

TONS COMMERCIAL SUGAR PER ACRE (T.S.A.)

Treatments	Age and month of harvest: 3 mos. Aug.	6 mos. Nov.	9 mos. Feb.	10 mos. Mar.	11 mos. Apr.	12 mos. May	15 mos. Aug.	18 mos. Nov.	21 mos. Feb.	24 mos. May	27 mos. Aug.
X	....	.46	2.8	3.7	4.9	5.1	5.8	5.9	6.5	6.6	5.5
A1	....	.44	5.7	6.2	8.1	8.9	10.6	12.6	10.3	11.4	8.3
B1	....	.33	5.2	6.9	9.5	9.6	11.6	11.8	13.0	14.0	9.5
C1	....	.16	5.3	5.9	8.6	9.9	12.0	11.5	15.8	13.5	10.4
A2	....	.94	4.4	5.6	6.6	7.4	9.2	11.0	14.5	11.6	10.2
B2	....	See A1	5.2	6.5	8.5	10.1	11.4	14.2	16.0	11.1	8.7
C2	....	See B1	4.9	6.2	9.9	9.9	10.3	12.8	13.6	14.0	8.8
A3	....	See A2	4.4	4.9	5.7	6.4	7.6	10.4	11.6	10.4	8.9
B3	....	See A1	See A1	See A1	See A1	8.8	10.2	13.2	14.2	13.6	10.2
C3	....	See A1	See B2	See B2	See B2	8.4	13.3	15.3	16.9	15.6	10.9
Avg.	....	.49	4.7	5.7	7.7	8.4	10.2	11.9	13.2	12.2	9.1
S.D.	....	.22	.72	.81	1.00	.99	1.40	1.60	1.89	1.78	2.17
C.V.	....	45.0	15.3	14.2	13.0	11.8	13.7	13.4	14.3	14.6	23.8
M.d.r.	....	*	*	*	*	1.3	1.8	2.1	2.4	2.3	2.8

TABLE 25

POUNDS NITROGEN PER ACRE FOUND IN TOTAL DRY WEIGHT

Treatments	Age and month of harvest: 3 mos. Aug.	6 mos. Nov.	9 mos. Feb.	10 mos. Mar.	11 mos. Apr.	12 mos. May	15 mos. Aug.	18 mos. Nov.	21 mos. Feb.	24 mos. May	27 mos. Aug.
X	26.97	111.91	77.42	61.04	65.87	56.99	48.33	51.28	46.82	45.70	47.44
A1	40.76	177.25	171.39	131.12	118.17	117.45	96.38	111.59	82.09	75.81	64.15
B1	See A1	233.08	229.33	197.55	199.42	159.17	132.96	128.33	109.33	97.18	69.97
C1	See A1	243.92	259.02	202.58	194.32	172.25	140.77	120.26	117.69	98.07	77.71
A2	See A1	112.90	141.59	114.27	107.14	107.29	100.58	95.07	96.42	75.44	75.10
B2	See A1	See A1	228.34	162.79	162.56	158.21	126.95	144.03	126.31	80.54	68.75
C2	See A1	See B1	269.51	202.65	218.39	182.35	152.50	154.48	128.52	111.16	77.33
A3	See A1	See A2	92.91	73.34	66.00	96.60	91.86	94.14	76.63	66.28	66.62
B3	See A1	See A1	See A1	See A1	See A1	135.87	145.85	142.28	110.61	87.59	75.48
C3	See A1	See A1	See B2	See B2	See B2	176.47	186.65	172.90	147.78	114.36	88.47
Avg.	39.38	175.67	183.57	143.21	141.60	136.26	122.28	121.44	104.19	85.21	71.10
S.D.	7.26	21.59	26.46	19.10	20.23	19.52	20.73	19.79	15.02	14.46	12.61
C.V.	18.4	12.3	14.4	13.4	14.3	14.3	17.0	16.3	14.4	17.0	17.7
M.d.r.	6 82	*	*	*	*	25.07	11.6	25.4	19.3	18.6	16.0

Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
MARCH 16, 1945, TO SEPTEMBER 15, 1945

Date	Per pound	Per ton
March 16, 1945—September 15, 1945	3.75¢	$75.00

TABLE OF CONTENTS